HINDU ASTRONOMICAL AND MATHEMATICAL TEXTS SERIES—5

THE
KARAṆA-RATNA
OF
DEVĀCĀRYA

Edited by

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DEPARTMENT OF MATHEMATICS AND ASTRONOMY
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WITH THE COMMENTARY OF

BHĀSKARA I AND SOMEŚVARA

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Āryabhaṭa—Indian mathematician and astronomer, *By* K. S. Shukla



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KARAṆA-RATNA

देवाचार्यकृतं

करणरत्नम्

KARAṆA-RATNA

OF

DEVĀCĀRYA

Critically Edited

and

Translated into English with Explanatory and Critical Notes and comments, etc.

by

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PREFACE

The object of the "Hindu Astronomical and Mathematical Texts Series" is to bring out authoritative and critical editions of important unpublished works dealing with ancient Hindu astronomy and mathematics. The present edition of Deva's *Karaṇa-ratna* is No. 5 of this series.

The idea of bringing out the above series is due to Dr A. N. Singh, late Professor of Mathematics, Lucknow University, who organised the scheme of research in the history of Hindu mathematics and astronomy in the Department of Mathematics and Astronomy, Lucknow University, with the object of collecting, studying and editing important works on Hindu mathematics and astronomy. Under his able supervision remarkable progress was made in this direction and a number of manuscripts were acquired, studied and edited. This work has been continued since his death in 1954 by our colleague, Dr Kripa Shankar Shukla, Professor of Mathematics, Lucknow University, who has already been actively engaged in this work since 1941.

The scheme of research in the history of Hindu mathematics and astronomy referred to above has been financed by the Government of Uttar Pradesh, through the help of late Dr Sampurnanand, its then Education Minister, for which we offer our sincere thanks to them. We are particularly indebted to Dr Sampurnanand for his help, interest and encouragement in the progress of our research during his lifetime.

The present publication of the *Karaṇa-ratna* have been made out of the generous grant sanctioned by the Council of Science and Technology, Uttar Pradesh, Lucknow. We record our gratefulness to the Council for kindly sanctioning the grant and making this publication possible.

R. P. Agarwal

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LIST OF ABBREVIATIONS

Ā	*Āryabhaṭīya* of Āryabhaṭa I (499 A.D.)
BrSpSi	*Brāhma-sphuṭa-siddhānta* of Brahmagupta (628 A. D.)
GCN	*Graha-cāra-nibandhana* of Haridatta
GCNS	*Graha-cāra-nibandhana-saṅgraha* (932 A. D.)
KK	*Khaṇḍa-khādyaka* of Brahmagupta (628 A. D.)
KKau	*Karaṇa-kaustubha* of Kṛṣṇa-daivajña (1653 A. D.)
KPr	*Karaṇa-prakāsa* of Brahmadeva (1092 A. D.)
KR	*Karaṇa-ratna* of Deva (689 A. D.)
KT	*Karaṇa-tilaka* of Vijayanandī (966 A. D.)
LBh	*Laghu-Bhāskarīya* of Bhāskara I (629 A. D.)
MakSā	*Makaranda-sāraṇī* of Makaranda (1478 A.D.)
MBh	*Mahā-Bhāskarīya* of Bhāskara I (629 A.D)
MSi	*Mahā-siddhānta* of Āryabhaṭa II (c. 950 A.D.)
PSi	*Pañca-siddhāntikā* of Varāhamihira (d. 587 A.D.)
ŚiDVṛ	*Śiṣya-dhī-vṛddhida* of Lalla (c. 749 A.D.)
SiŚe	*Siddhānta-śekhara* of Śrīpati (c. 1039 A D.)
SiŚi	*Siddhānta-śiromaṇi* of Bhāskara II (1150 A D.)
SMT	*Sumati-mahā-tantra* of Sumati
SpNiT	*Sphuṭa-nirṇaya-tantra* of Acyuta (d. 1621 A. D.)
SūSi	*Sūrya-siddhānta*
Vāka	*Vākya-karaṇa* of Sundararāja (c. 1300 A D.)
VSi	*Vaṭeśvara-siddhānta* of Vaṭeśvara (904 A.D.)

INTRODUCTION

The *Karaṇa-ratna*, edited here for the first time, deals with astronomy and is a composition of astronomer Deva, son of Gojanma, who lived in the second half of the seventh century A. D. and belonged to South India, probably Kerala.

THE AUTHOR

The name of the author of the *Karaṇa-ratna* is mentioned in the opening verse of the work and also in the closing verses of the various chapters. In all these places the author calls himself Deva. In the colophon occurring at the end of the eighth chapter, the author has been called Devācārya i. e., Ācārya Deva.

In the closing verse of the fourth chapter, Deva has called himself "son of Gojanma" and in the opening verse of the first chapter, Gojanma is said to have been a devotee of the gods Viṣṇu, Śiva and Brahmā. In the opening verse of the first chapter, Deva himself has paid homage to the same gods. It seems that Deva, too, like his father, was a devotee of Viṣṇu, Śiva and Brahmā. Invocation to Lord Kṛṣṇa (an incarnation of Viṣṇu) in the beginning of Chapter 2 and to God Śiva in the beginning of Chapter 7 also point to the same conclusion.

The epoch used in the computations of the *ahargaṇa* ("the number of days elapsed") and the mean longitudes of the planets is the beginning of the year 611 (elapsed) of the *Śaka* era, which corresponds to the year 689 of the Christian era. This shows that the author flourished in the seventh century A. D. and composed the *Karaṇa-ratna* in 689 A. D., exactly 60 years after Bhāskara I wrote his commentary on the *Āryabhaṭīya* and 24 years after Brahmagupta wrote his *Khaṇḍakhādyaka*.

The *Karaṇa-ratna* does not throw light on any other personal details of its author except showing that he was a great scholar versed in all

astronomical works of his time particularly those of the Āryabhaṭa school. The place of birth or activity of the author is also not exactly known. There are, however, reasons to believe that he belonged to South India, probably Kerala. The following facts deserve mention in this connection :

1. The available palm-leaf manuscript of the *Karaṇa-ratna* was discovered in Kerala and was inscribed in *Malayalam*, the regional script of the Kerala country.

2. For expressing numbers in verse, the *Karaṇa-ratna* employs the word-numerals as well as the letter-numerals of the so called *Kaṭapayādi* system. Both these numerals were commonly used by the Kerala astronomers.

3. The author of the *Karaṇa-ratna* states three *bīja* (parametric) corrections, viz. (1) the *Śakābda* correction, (2) the *Kalpa* correction, and (3) the *Manuyuga* correction. The *Śakābda* correction is supposed to have been devised by the Kerala astronomer Haridatta in 683 A.D., i. e., 6 years before the composition of the *Karaṇa-ratna.* The *Kalpa* correction is referred to by the Kerala astronomer Parameśvara (A. D. 1431) in his commentary on the *Laghu-Bhāskarīya* (i. 37) of Bhāskara I but it has not been found to occur in any other work so far. The *Manuyuga* correction has been mentioned by the Kerala astronomers Śaṅkaranārāyaṇa (869 A.D.) and Nīlakaṇṭha (1500 A.D.). Both these astronomers thought that this correction was probably due to Āryabhaṭa I. The *Karaṇa-ratna* is the earliest preserved work where the above three corrections are stated in their proper form.

4. The method used in the *Karaṇa-ratna* for the computation of a solar eclipse is a typical south Indian method. The same method with some modification reappears in the *Grahaṇāṣṭaka* and the *Grahaṇa-maṇḍana* of the Kerala astronomer Parameśvara (1431 A.D.) and in the *Vākya-karaṇa* of Sundararāja (c. 1300 A. D.).

5. A reference to the *Karaṇa-ratna* along with a quotation from it occurs in the *Jyotirmīmāṁsā* of the Kerala astronomer Nīlakaṇṭha (1500 A. D.); the passage quoted consists of vss. 3-4(a-b) of the first chapter. Another quotation from the *Karaṇa-ratna* occurs in the Kerala astronomer Parameśvara's commentary on the *Laghu-Bhāskarīya* (ii. 16); the passage quoted in this case is the verse 36 of the first chapter.

HIS SCHOOL

Deva was a follower of Āryabhaṭa I. In the second verse of the first chapter of the *Karaṇa-ratna* he himself says :

> "Having taken a deep plunge into the entire ocean of the *Āryabhuṭa-śāstra* with the help of the boat of intellect, I have brought out this jewel, the *Karaṇa-ratna* radiant with the rays of all the planets."

By 'the entire ocean of the *Āryabhaṭa-śāstra*' Deva means not only the *Āryabhaṭīya* and the works based on it but also the *Āryabhaṭa-siddhānta* which was summarised by Brahmagupta in his *Khaṇḍakhādyaka*. For, although the *Karaṇa-ratna* is essentially based on the teachings of Āryabhaṭa I as found in the *Āryabhaṭīya*, it is highly influenced by the *Khaṇḍakhādyaka*. The divisors used in the *Karaṇa-ratna* for finding the intercalary months and the omitted lunar days in the computation of the *ahargaṇa* are exactly the same as those used in the *Khaṇḍakhādyaka*. Following the *Khaṇḍakhādyaka* the *bhujāvivara* correction has been omitted in the case of the Sun; and in the case of the Moon too the rule stated is the same as that given in the *Khaṇḍakhādyaka*. The *śīghrakendras* corresponding to the risings and settings and commencement of retrograde and direct motions, given in the *Karaṇa-ratna*, are more or less the same as those stated in the *Khaṇḍakhādyaka*. Quite a few other rules of the *Karaṇa-ratna* have their counterparts in the *Khaṇḍakhādyaka*.

Sometimes the teachings of the *Khaṇḍakhādyaka* are adopted after introducing some changes or modifications in them. Thus whereas in the *Khaṇḍakhādyaka* the radius of the circle is assumed to contain 150′, in the *Karaṇa-ratna* it is exactly double of that. Similarly, while the sine-table of the *Khaṇḍakhādyaka* gives the sines for every 15° of the quadrant, the sine-table of the *Karaṇa-ratna* gives the sines of every 10°. The same is true also for the declination table.

It is interesting to note that although Deva is an admirer and follower of Bhāskara I and has adopted a number of verses from his *Laghu-Bhāskarīya*, he does not agree with his interpretations of Āryabhaṭa I's rules for finding the *valana* and the *dṛkkarma*. Rather he is in agreement with the teachings of the *Pūrva-Khaṇḍakhādyaka*. He has also adopted as many as three verses from the *Pūrva-Khaṇḍakhādyaka*.

Sometimes Deva adopts the teachings even of the *Uttara-Khaṇḍa-khādyaka* in preference to the corresponding teachings of Āryabhaṭa I. Thus instead of following Āryabhaṭa I's or Bhāskara I's rules for finding the celestial latitudes of the Moon and of the planets, he follows the rules given in the *Uttara-Khaṇḍakhādyaka.* In the case of the prediction of an eclipse, he not only prefers to follow the rule of the *Uttara-Khaṇḍa khādyaka* but also adopts verbatim the rule of the *Uttara-Khaṇḍakhādyaka.*

Deva does not hesitate even in adopting rules from the *Brāhma-sphuṭa-siddhānta* of Brahmagupta. Deva's rules for finding the gnomonic shadow from time and *vice versa* are undoubtedly adaptations from Brahmagupta. (See ch. iv, vss. 8-9, 11-13)

Impact of the *Sūrya-siddhānta* and the writings of Varāhamihira is also clearly perceptible at places.

This all goes to prove that Deva was a well-read scholar, and although he belonged to Āryabhaṭa I's school of astronomy, he was not a blind follower of Āryabhaṭa I.

THE *KARAṆA-RATNA*

Hindu works on astronomy are generally classified into three categories: (1) *Siddhānta,* (2) *Tantra,* and (3) *Karaṇa.* Deva's *Karaṇa-ratna,* as this name itself suggests, is of the third category. Works of this category are manuals or handbooks of astronomy which set out rules aiming not so much at accuracy as at brevity, conciseness, simplicity, and above all facility of computation. Such a work adopts a convenient date in the year of its composition as the zero-point of calculation. The zero-point adopted in the *Karaṇa-ratna* is the beginning of the month of *Caitra* in the year 689 A. D. The day is supposed to begin at sunrise as in the *Āryabhaṭīya.*

The aim of writing the *Karaṇa-ratna* and the scope of the work have been clearly stated by Deva himself. Writes he :

> "The *Karaṇa* texts of ancient times do not yield accurate results either because of dullness of pupils' intellect or because of the cryptic teaching of the preceptor, or else, because of the inexactitude of the multipliers and divisors. They say that the aim of acquiring knowledge of astronomy was to rectify and re establish the obsolete methods or to discover and highlight new methods. Hence this attempt of mine."

The subject matter of the *Karaṇa-ratna* is divided into eight chapters :

Chapter 1, dealing with the computation of the true positions of the Sun and Moon, and the elements of the *Pañcāṅga*.

Chapter 2, dealing with the computation and graphical representation of the lunar eclipse.

Chapter 3, dealing with the computation of the solar eclipse.

Chapter 4, dealing with the problems based on the gnomonic shadow.

Chapter 5, dealing with the time of moonrise and related problems.

Chapter 6, dealing with the heliacal visibility of the Moon and the elevation of the lunar horns.

Chapter 7, dealing with the positions of the planets.

Chapter 8, dealing with planetary motion and planetary conjunction.

The above contents will show to the reader that the *Karaṇa-ratna* deals with almost every aspect of planetary astronomy recognized by the Hindu astronomers. A careful study of the work will further reveal that this work contains a very valuable record of the methods and techniques employed by the astronomers of South India in the seventh century A.D. Although we possess one more work of a similar nature written in Kerala about the same time, viz. the *Graha-cāra-nibandhana* of Haridatta, but the scope of this work is limited to finding the positions of the planets and their application to finding the *tithis* and *nakṣatras* only and it does not throw light on the other aspects of Hindu astronomy.

The order of treatment of the subject matter of the *Karaṇa-ratna* differs from the order generally prevailing in the other works on Hindu astronomy in so far that in the *Karaṇa-ratna* the subject of eclipses occurs earlier than the treatment of the problems on the gnomonic shadow. In other works, the order is just the reverse of it.

Amongst the notable features of the *Karaṇa-ratna* may be mentioned the following :

1. *Mean longitudes from the omitted lunar days elapsed* (*avama*) and *the residue of the omitted lunar days* (*avamaśeṣa*). (i. 9-15)

The mean longitudes of the planets are obtained by Hindu astronomers usually with the help of the *ahargaṇa*, but Deva has obtained the mean longitudes of the Sun, Moon, Moon's apogee, and Moon's ascending node from the omitted lunar days elapsed and the residue of the omitted lunar days. The rules given by Deva have no counterpart in any other work on Hindu astronomy, except in the case of the Moon.

2. *The Śakābda, Manuyuga and Kalpa corrections.* (i. 16-18, 19, 20-21)

These corrections, as already noted, occur for the first time in the *Karaṇa-ratna*.

3. *Precession of the equinoxes.* (i. 36)

Deva is probably the first in the school of Āryabhaṭa I to have given a rule for finding the value of the precession of the equinoxes. He bases his rule on the assumption that the motion of the equinoxes is oscillatory and that its rate is about 47″ per annum. The modern value is about 50″ per annum.

4. *Relation between latitude and equinoctial midday shadow.* (i. 33 (c-d); iii. 4)

Deva gives the following rules :

(1) equinoctial midday shadow (in *aṅgulas*)

$$= \frac{\text{distance (in } yojanas\text{) from the equator}}{41}$$

(2) local latitude (in degrees) $= \dfrac{27 \text{ (equinoctial midday shadow in } aṅgulas\text{)}}{7}$

Evidently these rules are impirical and crude. It is noteworthy that similar rules reappear in the writings of later Kerala astronomers.[1]

5. *Use of Vikṣepa-valana in the graphical representation of the eclipses.* (iii. 12 (c-d)-14 (a-b))

1. If in place of स्वत्र्यंश in vs. 4 of ch. 3, the correct reading is स्वत्रिंश, then 27/7 in this formula should be replaced by 1080/217 or 5 approx

Bhāskara I makes use of the Moon's latitude directly in the graphical representation of the eclipses. Deva, on the other hand, makes use of the so called *Vikṣepa-valana*. Deva's definition of the *Vikṣepa-valana* is his own invention.

6. *Ayanavalana* and *Akṣavalana*. (iii 14 (c-d)-17 (a-b)).

Deva's rules for finding the *Ayanavalana* and the *Akṣavalana* are slightly different from those given by Āryabhaṭa I and Bhāskara I and deserve notice.

7. *Midday shadow from meridian zenith distance*. (iv. 2 (d)-5)

Deva gives a special rule for finding the midday shadow of the gnomon from the meridian zenith distance of the Sun.

8. *Application of a third visibility correction to the Moon*. (See v. 4)

Besides the two visibility corrections, *Ayana-dṛkkarma* and *Akṣa-dṛkkarma*, Deva prescribes the use of a third visibility correction to the Moon in order to make it fit for observation at the horizon. This correction is probably meant to account for the horizontal parallaxes of the Sun and Moon.

9. *Absence of steller astronomy.*

Although the *Karaṇa-ratna* deals with all the aspects of planetary astronomy, the treatment of the stars, such as their positions and conjunction of planets with them, is absent from it. This omission is perhaps done deliberately for, being a *Karaṇa*, it is not a full-fledged work on astronomy and is meant essentially to cater to the needs of the *Pañcāṅga* makers.

10. *Use of unusual terms.*

Deva uses two terms which sound rather unusual, viz. *phaṇi* and *karaṇa*. *Phaṇi* is used in the sense of "Earth's shadow" and also in the sense of "Moon's ascending node". *Karaṇa* is used to denote the number 13.

The only other work which uses the word *phaṇi* in the above senses is the *Brahma-siddhānta* of the *Śākalya-saṁhitā*.

11. *Statement of the synopsis of each chapter in the closing verse.*

In the closing verse (or verses) of each chapter, Deva briefly states the topics dealt with in that chapter. Such a thing is not found to occur in any other work on Hindu astronomy, and forms a special feature of the present work.

CHAPTER ON *MAHĀPĀTĀ* ASCRIBED TO THE *KARAṆA-RATNA*

A chapter devoted to the treatment of the phenomena of *Mahāpāta* has been added as Appendix I to the present work. In two manuscripts of this chapter existing in the Government Oriental Library, Mysore, this chapter is entitled "Chapter on *Mahāpāta* in the *Karaṇa-ratna*". Although this title seems to suggest that this chapter is taken from the *Karaṇa-ratna*, it undoubtedly does not belong to the *Karaṇa-ratna*. There are also reasons to believe that it cannot be a composition of Deva, the author of the *Karaṇa-ratna*. For :

1. A number of teachings of this chapter are contradictory to those of the *Karaṇa-ratna*. For example, whereas, according to the *Karaṇa-ratna*, the rate of precession of the equinoxes is 47″ per annum, the same, according to this chapter, is 54″ per annum. Similarly, the rules for finding the diameters of the Sun and the Moon stated in this chapter are different from those stated in the *Karaṇa-ratna*.
2. Some of the verses of the chapter on *Mahāpāta* are of a much later date. For example, one verse (viz. vs. 28) is taken from the *Karaṇa-prakāśa* of Brahmadeva, which was written in A. D. 1092. Similarly, another verse (*viz*. vs. 19) employs the *Kali-Ahargaṇa* 1538937, which corresponds to some date in A. D. 1112. A number of verses are adaptations from the modern *Sūrya-siddhānta*.

The chapter on *Mahāpāta* seems to be a hotch-potch of verses dealing with the subject collected from various sources by some unknown writer. This is borne out by the lack of arrangement of the subject matter and too much of repetition of the same matter which is sometimes inconsistent and contradictory.

The process of collection and interpolation of verses seems to have continued for quite some time for out of the two manuscripts available to us, one (viz. C) contains 13 verses more than the other (viz. B). And, out of these 13 verses too, one verse finds insertion at one place and the remaining 12 at the other. These two insertions might have been made at two different times.

We tried to locate the sources of the verses of the chapter on *Mahāpāta* and have been able to trace the source in the case of some of them. For example, it has been found that 7 verses (viz., vss. 1, 2, 4, 46, 50, 51, and 52) are undoubtedly from the *Sūrya-Siddhānta* which have been adopted with or without alteration, and 1 from the *Karaṇa-prakāśa* of Brahmadeva (A. D. 1092) which has been taken without any alteration. Eight

verses and a half (viz., vss. 20(a-b), 33, 34-35(a-b), 36, 37, 38(a-b), 39, 41 and 42) have been taken, with or without alteration, from the *Karaṇa-ratna.* The sources of the remaining verses are unknown at present.

In spite of all this, we have chosen to include this chapter on *Mahāpāta* in the present work, because as many as 8½ of the borrowed verses have heen taken from the *Karaṇa-ratna* and because some of the teachings of this chapter are quite new and of sufficient historical interest.

MANUSCRIPT MATERIAL

The present edition of the *Karaṇa-ratna* is based on the following manuscript (which is a transcript of a palm-leaf manuscript) :

A Ms. No. T. 559 of the Kerala University Oriental Institute and Manuscripts Library, Trivandrum. Substance—Paper. Character—*Devanāgarī*. Size—13″ × 8½″. Extent—24 pages, with 20 lines per page and 18 letters per line. No. of *granthas*—300. Complete. Date of transcript—14th day of the month Leo in the year 1097 A. D.

The details of the original palm-leaf manuscript are as follows:

Substance—Palm-leaf. Character—*Malayalam*. Owner of manuscript—Cirakkal Kovilakam. Name of scribe—N. Rāmanuṇṇi.

The chapter on *Mahāpāta,* occurring as Appendix 1 of the present edition, is based on the following two manuscripts (B and C) :

B Ms. No. B 576 of the Government Oriental Library, Mysore.

The details of this manuscript are as follows :

No. of Ms.—B. 576. Material—Paper. Script—*Kannaḍa.* Leaves in Ms.—159-163. Subject—*Jyotiṣam.* Extent—Incomplete but in good condition.

It begins with :

करणरत्ने महापाताध्याय: ।
शुभमस्तु । गणाधिपतये नम: ।
एकायनगतौ स्यातां सूर्यचन्द्रमसौ यदा ।

etc. etc.

and ends thus :

क्रान्तिस्फुटा च यदा तदानीमसम्भवत्येव हि पातयोग: ।। ४० ।।
हरि: ओं । कृष्णार्पणमस्तु । इति करणरत्ने महापाताध्याय: ।

[यादृशं पुस्तकं दृष्टं तादृशं लिखितं मया ।
अबद्धं वा सुबद्धं वा मम दोषो न दीयते ।।]

C Ms. No. P 4477 of the Government Oriental Library, Mysore.

The details of this manuscript are as follows :

No. of Ms.—P 4477. Material—Palmleaf. Script—*Nandīnāgarī*. Leaves in Ms.—49-52. Subject—*Jyotiṣam*. Extent—Incomplete.

It begins with :

श्री: ।

करणरत्ने महापाताधिकार: ।
एकायनगतौ स्यातां सूर्याचन्द्रमसौ यदा ।

etc. etc.

and ends with :

क्रान्ति: स्फुटाल्पा च यदा तदानीमसम्भवत्येव हि पातयोग: ।। ५३ ।।
इति करणरत्ने महापाताधिकार: ।

[यादृशं पुस्तकं दृष्टं तादृशं लिखितं मया ।
अबद्धं वा सुबद्धं वा मम दोषो न विद्यते ।।]

EDITORIAL NOTE

The manuscripts used were complete and generally in good condition. The errors were few and easy to correct and it was also not difficult to supply the missing letters for the omissions that existed. In the case of the *Karaṇa-ratna*, we had only one manuscript and had to rely on the text presented by it. A discrepanacy was however noted as regards the extent of the text. There were actually 176 verses in the manuscript but the post-colophonic statement at the end of the eight chapter gave the total extent of the work as 167 verses. The verses adopted from the *Laghu-Bhāskarīya* (viz. i. 27, 28, 29 and iii. 17(c-d)) and from the *Khaṇḍakhādyaka* or *Brāhma-sphuṭa-siddhānta* (viz. i. 39, 46, 58, 59, and ii. 6) were probably

excluded while fixing the extent of the work. The edited text contains all the 176 verses because all these verses were numbered in the manuscript and there was no reasonable ground to exclude any one of them. In the case of the *Mahāpātādhyāya*, (i. e. the chapter on *Mahāpāta*), the number of verses in the two manuscripts used were different. B contained 42 verses, whereas C contained 13 additional verses. The edited text gives all the 55 verses; but in order to distinguish the 13 additional verses of C from the rest, these verses have been printed in smaller black types.

The manuscripts used set out in continuous succession the verses of the various chapters, but did not indicate the subject matter dealt with in the verses. In the edited text, in order to facilitate the understanding of the text, the verses dealing with different topics have been grouped together and suitable headings in English, briefly indicating the subject matter treated in those verses, have been supplied to them. The letters or words supplied to fill the omissions in the text or the numerical figures given after the number chronograms to facilitate comprehension have been enclosed within square brackets. The reader will thus note that the portions within the square brackets did not form part of the text but are editorial additions.

In editing the text, it was sometimes necessary to alter and rectify the text in order to preserve the accuracy of the text. Wherever such alteration is made, the original reading is shown in the footnote. Care has however been taken to make as few alterations as possible. Quotations from the text or parallel passages found to occur in other works have helped in checking and rectifying the text.

ENGLISH TRANSLATION

The English translation is, as far as possible, a literal rendering of the Sanskrit text. Verses dealing with the same topic have been translated together and are preceded by an introductory heading briefly summarising their contents. The portions of the English translation within brackets do not occur in the text and have been given in the translation to make it understandable and are at places explanatory. The translation is followed by short notes and comments comprising (i) elucidation of the text where necessary, (ii) *rationale* of the rules given in the text, (iii) critical notes, and (iv) other relevant matter, depending on the nature of the passage translated. Parallel passages occurring in other works on Hindu astronomy have been indicated in the footnotes and the interested reader might refer to them if necessary.

ACKNOWLEDGEMENTS

The manuscript of the *Karaṇa-ratna* used in the preparation of the present edition was procured for my use from the Kerala University Oriental Institute and Manuscripts Library, Trivandrum, by Dr B. V. Subbarayappa, then Executive Secretary, Indian National Science Academy, New Delhi, and the two manuscripts of the chapter on *Mahāpāta* from the Government Oriental Library, Mysore, by the Hony. Librarian, Lucknow University Library, Lucknow. My sincere thanks are due to Dr B. V. Subbarayappa and the Hony. Librarian of the Lucknow University Library as also to the authorities of the manuscripts libraries at Trivandrum and Mysore who kindly supplied the manuscripts.

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K. S. Shukla

CHAPTER 1

THE SUN AND MOON AND THE *PAÑCĀṄGA*

INVOCATION AND AUTHORSHIP

हरिहरहिरण्यगर्भान् प्रणम्य गोजन्मवन्दितान् भक्त्या ।
ग्रहचारं व्यक्ततरं कथयति देवः समासेन ॥१॥

1. **Having paid obeisance to *Viṣṇu*, *Śiva* and *Brahmā* who were adored by Gojanma with devotion, Deva sets out the motion of the planets briefly but more clearly.**

Gojanma is the name of Deva's father. See *infra*, ch. iv, vs. 17.

SOURCE

आर्यभटशास्त्रजलधिं मतिनावा दूरमखिलमवगाह्य ।
लब्धं मयेदमखिलग्रहांशुजटिलं करणरत्नम् ॥२॥

2. **Having taken a deep plunge into the entire ocean of the *Āryabhaṭa-śāstra* with the help of the boat of intellect, I have brought out this jewel, the *Karaṇa-ratna*, radiant with the rays of all the planets.**

DRAWBACKS OF ANCIENT *KARAṆA* TEXTS

शिष्यस्य बुद्धिमान्द्यादाचार्यस्योपदेशसंवरणात् ।
गुणभागयोश्च शेषात् पुराणकरणानि न घटन्ते ॥३॥

3. **The *Karaṇa* texts of ancient times do not yield accurate result either because of the dullness of pupil's intellect, or because of the cryptic teaching of the precepter, or else, because of the inexactitude of the multipliers and divisors.**

AIM OF THE PRESENT WORK

नष्टानि स्थापयितुं नवानि करणानि च प्रकाशयितुम् ।[1]
तन्त्रज्ञानस्य फलं वदन्ति तदयं ममोत्साहः[2] ॥४॥

4. They say that the aim of acquiring knowledge of astronomy (*tantra-jñāna*) is to rectify and re-establish the obsolete methods or to discover and highlight new methods. Hence this attempt of mine.

AHARGAṆA

शकवर्षं रुद्ररसै[६११] रहितं रवि[१२]सङ्गुणं सगतमासम् ।
त्रिंशद्[३०]गुणं तिथियुतं तृतीयमिषुवेदनवमनुभिः
[१४९४५] ॥५॥

लब्धं मध्ये त्यक्त्वा युक्त्वाऽत्र स्वरदहनवसून्[८३७] हृत्वा ।
रसमुनिनवभि[९७६]र्लब्धान् मासान् त्रिंशद्[३०]गुणानधिकान् ॥६॥

उपरि क्षिप्त्वा त्रिरधः शरयमगुणखाग्नि[३०३२५]भिर्हृतं[3] मध्ये ।
रुद्र[११]गुणे संयोज्यं[4] वेदाम्भोनिधिरसा[६४४]श्चात्र ॥७॥

लब्धानि त्रिखशैलै[७०३]र्नष्टदिनानि व्यपोह्य तान्युपरि ।
शुद्धदिनं तं मुनिहृतशेषे शुक्रादिदिनपः स्यात् ॥८॥

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1. Vss. 3-4 (a–b) have been quoted by Nīlakaṇṭha in his *Jyotirmīmāṁsā*, where we have गुणहारयोश्च in place of गुणभागयोश्च and करणानि नवानि in place of नवानि करणानि. *See Jyotirmīmāṁsā*, ed. K. V. Sarma, p. 9.

2. A. महोत्साहः

3. A. त for तं

4. A. य for यं

5-8. Diminish the (current) *Śaka* year by 611, then multiply by 12, then add the number of months elapsed (since the beginning of the month of *Caitra*), then multiply by 30, and then add the number of *tithis* (lunar days) elapsed (of the current month). (Set down this result in three places one below the other). Divide the result in the third (lowest) place by 14945, then subtract the quotient (obtained) from the result occupying the middle place, then add 837, then divide by 976, then multiply the resulting intercalary months by 30, and then add what is obtained to the result in the uppermost place. Set down this result (again) in three places. Divide the result in the lowest place by 30325, add it to 11 times the result in the middle place, then add 644, then divide the sum by 703, and then subtract the resulting omitted lunar days from the result in the uppermost place. This is known as *Śuddha-dina* (or *Ahargaṇa*). This being divided by 7, the remainder counted from Friday gives the lord of the current day.[1]

Thus, to find the *Ahargaṇa* for $(T+1)$th *tithi* in the $(M+1)$th month of *Śaka* year S (elapsed), one has to proceed along the following steps :

Step 1 : $S - 611 = A$, say.
Step 2 : $12\,A + M = B$, say.
Step 3 : $30\,B + T = C$, say.
Step 4 : $C + \left[\left\{(C - C/14945) + 837\right\}\frac{1}{976}\right] \times 30 = D$, say.
Step 5 : $D - \left[(11\,D + D/30325) + 644\right]\frac{1}{703} = Ahargaṇa$.

Explanation.—A denotes the number of mean solar years elapsed since the mean *meṣa-saṅkrānti* of the *Śaka* year 611 up to the mean *meṣa saṅkrānti* of the current *Śaka* year. B denotes the number of mean solar months elapsed since the mean *meṣa-saṅkrānti* of the *Śaka* year 611 up to the beginning of the $(M+1)$th mean solar month of the current year. C denotes the number of mean solar days elapsed since the mean *meṣa-saṅkrānti* of the *Śaka* year 611 up to the beginning of the $(T+1)$th mean solar day of the $(M+1)$th mean solar month of the current year.

The number of mean intercalary months corresponding to C mean solar days (using Āryabhaṭa I's parameters)

1. *Cf.* *KK* (=*Khaṇḍa-Khādyaka*), I. i. 3-5.

$$= \frac{1593336\ C}{4320000 \times 360}$$
$$= \frac{1}{976} \cdot \frac{1593336 \times 976\ C}{4320000 \times 360}$$
$$= \frac{1}{976} \cdot \left[(C - C/14935) \right].$$

Therefore, the number of mean lunar days elapsed since the mean *meṣa-saṅkrānti* of *Śaka* year 611 up to the beginning of the $(T+1)$th mean lunar day of the current lunar month

$$= C + \left[(C - C/14935) \right] \times \frac{1}{976} \times 30,$$

taking the quotient only of each division.

Now, the number of mean intercalary months elapsed at *meṣa-saṅkrānti* of the *Śaka* year 611 since the beginning of *Kaliyuga*

$$= \frac{1593336 \times (3179 + 611)}{4320000}$$
$$= 1397 + 837/976,$$

so that the fraction of the mean lunar month lying between the beginning of *Caitra* of the *Śaka* year 611 (which is the epoch of the present work) and the mean *meṣa saṅkrānti* of the *Śaka* year 611

$$= 837/976.$$

Therefore, the number of mean lunar days elapsed since the beginning of *Caitra* of the *Śaka* year 611 up to the beginning of the $(T+1)$th mean lunar day of the current lunar month

$$= C + \left[(C - C/14935) \right] \frac{1}{976} \times 30 + \frac{837}{976} \times 30$$
$$= C + \left[\left\{ (C - C/14935) + 837 \right\} \frac{1}{976} \right] \times 30,$$

taking the quotient only of each division.

Thus, D denotes the number of mean lunar days elapsed since the epoch (i. e., the beginning of *Caitra* of *Śaka* 611).

The number of mean omitted lunar days corresponding to D mean lunar days

$$= \frac{25082580\ D}{1603000080}$$
$$= \frac{1}{703} \cdot \frac{25082580 \times 703\ D}{1603000080}$$
$$= \frac{1}{703} \cdot (11D + D/30325).$$

Now, the number of mean lunar months elapsed at the epoch since the beginning of *Kaliyuga*

$$= (3179 + 611) \times 12 + 1397$$

$$= 46877$$

and likewise the number of mean omitted days elapsed at the epoch since the beginning of *Kaliyuga*

$$= \frac{25082580 \times 46877}{53433336}$$

$$= 22004 + 644/703.$$

Therefore, the fraction of a mean lunar day between the beginning of *Caitra* of the *Śaka* year 611 and the succeeding sunrise = 644/703.

Hence, the number of mean civil days elapsed since mean sunrise on the first *tithi* of *Caitra* in *Śaka* 611 up to sunrise on the given day, i. e.,

$$Ahargaṇa = D - \frac{1}{703}\left[(11D + D/30325) + 644\right],$$

taking the quotient only of each division.

Again, the number of mean civil days elapsed at the beginning of the *Śaka* year 611 since the commencement of *Kaliyuga*

$$= 46877 \times 30 - 22004$$

$$= 1406310 - 22004$$

$$= 1384306$$

$$\equiv 0 \pmod 7.$$

Therefore, the *Śaka* year 611 started on the same day as *Kaliyuga* i. e., on Friday. Hence the *Ahargaṇa*, calculated according to the rule in the text, being divided by 7, the remainder counted from Friday yields the lord of the current day. The day is supposed to begin at sunrise. (*See* vs. 10 below).

For further details regarding the *Ahargaṇa*, see my notes on *MBh* (= *Mahā-Bhāskarīya*), i. 4-6.

MEAN LONGITUDES

1. SUN AND SUN'S APOGEE

द्युगणे गुणयम[२३]रहिते द्विष्ठे त्यक्त्वाऽवमानि तान्युपरि ।
अधरे त्रिगुणं [९] त्यक्त्वा नष्टं[1] हित्वा च नष्टशेषं च ॥९॥

नवनन्दरसै [६९९] र्लब्धं दत्त्वोपरि खरसगुण
[३६०] विशुद्धेंऽशाः ।
रविमध्यममुदयगतं मङ्गलगिरय[७८]स्तदुच्चांशाः ॥१०॥

9-10. Subtract 23 from the *Ahargaṇa* and set down the remainder in two places (one below the other). From the upper number subtract the *avama* days (elapsed since the epoch). From the lower number subtract 9, the *avama* days as also the *avamaśeṣa*, then divide by 699, and then add the quotient obtained to the upper number. (If it is greater than 360), subtract 360 from it. The resulting quantity is the mean longitude of the Sun at sunrise (at *Laṅkā*), in terms of degrees.

The longitude of the Sun's apogee is 78°.[2]

That is,

Sun's mean longitude = ($A - 23 -$ *avama* days) degrees

$$+ \frac{A - 32 - \text{avama days} - \text{avamaśeṣa}}{699} \text{ degrees}$$

$$+ \frac{\text{avamaśeṣa}}{1960} \text{ minutes,}^{3} \qquad (1)$$

and Mean longitude of Sun's apogee = 78°. (2)

The rationale of formula (1) is as follows :

According to Āryabhaṭa I,

---

1. A. दत्त्वा षष्टिं
2. See *Ā* (=*Āryabhaṭīya*), i. 9 ; *GCN* (=*Grahacāranibandhana*), iii. 32.
3. For these minutes see vss. 15-16 below.

Civil days in a *yuga* = 1577917500

Avama days in a *yuga* = 25082580

difference = 1552834920.

Therefore, assuming A for the *Ahargaṇa*, we have

$$\text{Sun's motion for } A \text{ days} = \frac{1555200000\ A}{1577917500} \text{ degrees}$$

$$= \frac{1555200000}{1552834920}\,(A - \textit{avama} \text{ days corresponding to } A),$$

where 1555200000 denotes the Sun's revolutions in a *yuga* multiplied by 360

$$= (1 + 1/699)\,(A - \textit{avama} \text{ days} - \textit{avamaśeṣa}/703) \qquad \ldots\ (3)$$

Now, the Sun's longitude at the epoch (*Ahargaṇa* = 1384306)

$$= \frac{1384306 \times 1555200000}{1577917500} \text{ degrees}$$

$$= 3789 \text{ revs. } 335^\circ\ (666/699)^\circ$$

$$= -24^\circ - (33/699)^\circ, \text{ neglecting revolutions.} \qquad \ldots(4)$$

From (3) and (4),

Sun's mean longitude at sunrise on the desired day (*Ahargaṇa* = A)

$$= (1+1/699)\,(A - \textit{avama} \text{ days} - \textit{avamaśeṣa}/703) - 24 -$$

$$- (33/699) \text{ degrees}$$

$$= (A - 24 - \textit{avama} \text{ days})$$

$$+ \frac{A - 33 - \textit{avama} \text{ days} - \textit{avamaśeṣa}}{699} \text{ degrees}$$

$$+ \textit{avamaśeṣa}\,(1/699 - 1/703) \times 60 \text{ minutes}$$

$$- \frac{\textit{avamaśeṣa}}{699 \times 703} \times 60 \text{ minutes}$$

$$= \left[(A - 24\text{—}avama \text{ days}) + \frac{A - 33 - avama \text{ days} - avama\acute{s}e\d{s}a}{699} \right] \text{degrees} + \frac{avama\acute{s}e\d{s}a}{2730} \text{ minutes.}$$

The rule stated in the text, however, has 23 in place of 24 and 1960 in place of 2730.

2. MOON

अवमदिवसस्य शेषं स्वशरयमां[२५]शान्वितं कला योज्याः ।
भानौ चात्र द्वादश[१२]गुणतिथ्योंऽशास्तु चन्द्रः स्यात् ॥११॥

11. To the Sun's mean longitude add degrees equal to 12 times the complete *tithis* (elapsed) and minutes equal to *avamaśeṣa* plus *avamaśeṣa* divided by 25. Thus is obtained the mean longitude of the Moon.[1]

That is,

Moon's mean longitude = Sun's mean longitude + 12 × (complete *tithis* elapsed) degrees + (1 + 1/25) *avamaśeṣa* minutes.

The rationale of this rule is as follows : We have

$$\frac{\text{Moon's mean longitude} - \text{Sun's mean longitude}}{12}$$

= *tithis* elapsed at sunrise

= (complete *tithis* elapsed + *avamaśeṣa*/692), lunar days treated as degrees.

Therefore,

Moon's mean longitude = Sun's mean longitude + 12 (complete *tithis* elapsed) degrees + $\frac{avama\acute{s}e\d{s}a \times 12}{692} \times 60$ minutes

= Sun's mean longitude + 12 (complete *tithis* elapsed) degrees + (1 + 1/25) *avamaśeṣa*, minutes,

because 720/692 = 1 + 1/25 approx.

---

1. *Cf. KK*, I, i. 9.

3. MOON'S APOGEE AND MOON'S ASCENDING NODE

वसुयम[२८]युतनष्टदिनं स्वर[७]गुणमात्मवसुरसनवां[९६८]शयुतम् ।
भागास्तच्चन्द्रोच्चे तस्मिन् त्र्यष्टक[३×८]कलाः क्षेप्याः ॥१२॥

कृतयम[२४]युतेऽवमदिने[1] नवक[९]हृते राशयस्तु तैरूनम् ।
चक्रं नवशशि[१९]लिप्ताहीनं राहोर्मुखं भवति ॥१३॥

12-13. To the *avama* days multiplied by 7, and then increased by 1/968 thereof, add 28. Thus are obtained the degrees of the longitude of the Moon's apogee. Add 24 minutes to it.

To the *avama* days add 24, and then divide by 9 ; these are signs. Subtract them from 12 signs, and then diminish the result by 19 minutes. Thus is obtained the longitude of the Moon's ascending node.

RESIDUAL CORRECTION TO THE MEAN LONGITUDES

एकोनशतेन [९९] हृतं नष्टदिनस्यावशेषमिन्दूच्चे ।
भागा योज्या राहोस्त्याज्या मुनिखाश्वि[२०७]भिर्लब्धाः ॥१४॥

गगनाङ्गनवैका[१९६०]प्ता देया लिप्ता रवौ तु चन्द्रोच्चे ।
द्विगुणितषष्ट्या शोध्या राहोर्वर्षाद् दशाद्[2] योज्या ॥१५॥

14-15. In the case of the Moon's apogee add degrees equal to *avamaśeṣa* divided by 99.

In the case of the Moon's ascending node, subtract degrees equal to *avamaśeṣa* divided by 207.

In the case of the Sun, add minutes equal to *avamaśeṣa* divided by 1960.

In the case of the Moon's apogee, subtract minutes equal to *avamaśeṣa* divided by 120.

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1. A. नवक्र

2. A. दशा

In the case of the Moon's ascending node, add 1 minute for every 10 years (elapsed since the epoch).

Thus,

Longitude of Moon's apogee $=[(7+7/968)($*avama* days$)+28]$ degrees
$+24$ minutes$+$*avamaśeṣa*$/99$ degrees $-$*avamaśeṣa*$/120$ minutes.

Longitude of Moon's ascending node $=$ 12 signs
(*avama* days$+24)/9$ signs 19′$-$*avamaśeṣa*$/207$ degrees
$+$(years elapsed since epoch)$/10$ minutes.

The rationale of these formulae is as follows :

According to Āryabhaṭa I :

Avama days in a *yuga* $= 25082580$

Revolutions of Moon's apogee in a *yuga* $= 488219$.

$\therefore$ Motion of Moon's apogee for 1 *avama* day

$$= \frac{488219}{25082580} \text{ revs.}$$

$$= 7(1+1/971) \text{ degrees.}$$

Deva takes $7(1+1/968)$ degrees instead of $7(1+1/971)$ degrees.

Therefore the motion of the Moon's apogee for

avama days $+$*avamaśeṣa*$/703$

avama days is equal to

$7(1+1/968)$ (*avama* days$+$*avamaśeṣa*$/703$ degrees
$=[7(1+1/968)$ (*avama* days$)+$*avamaśeṣa*$/99]$ degrees

$$-\frac{avama\acute{s}e\d{s}a \times 10 \times 60}{99 \times 703} \text{minutes}$$

$=[7(1+1/968)$ (*avama* days$)+$*avamaśesa*$/99]$ degrees
$-$ *avamaśeṣa*$/115$ minutes
$=[7(1+1/968)$ (*avama* days$)+$*avamaśeṣa*$/99]$ degrees
$-$ *avamaśeṣa*$/120$ minutes, approx.

Now the longitude of Moon's apogee at the epoch (*Ahargaṇa* $= 1384306$)

$$= \frac{1384?06 \times 488219}{1577917500} \text{ revs.} + 3 \text{ signs}$$

$$= \frac{67580434614}{1577917500} \text{ revs.} + 3 \text{ signs}$$

$= 42$ revs. 9 signs $28^\circ\ 24' + 3$ signs

$= 43$ revs. $28^\circ\ 24'$, or $28^\circ\ 24'$, neglecting revolutions.

Therefore,

longitude of Moon's apogee for the desired day

$= [7(1 + 1/968)$ (*avama* days)$+ 28]$ degrees$+ 24'$

$+$ *avamaśeṣa*/99 degrees $-$ *avamaśeṣa*/120 minutes.

Again, according to Āryabhaṭa I,

Avama days in a *yuga*$= 25082580$

Revolutions of Moon's ascending node in a *yuga*$= 232226$.

∴ Motion of Moon's ascending node for 1 *avama* day

$$= \frac{232226}{25082580} \text{ revs.}$$

$= [1/9 - 2172/25082580 \times 9]$ signs.

∴ Motion of Moon's ascending node for

avama days$+$*avamaśeṣa*/692

avama days is equal to

$$\left[\frac{\textit{avama}\text{ days}}{9} + \frac{\textit{avamaśeṣa}}{692 \times 9} - \frac{2172 \times (\textit{avama}\text{ days})}{25082580 \times 9}\right] \text{signs}$$

$$= \frac{\textit{avama}\text{ days}}{9} \text{ signs} + \frac{\textit{avamaśeṣa}}{207} \text{ degrees}$$

$$- \frac{2172 \times 1800 \times \textit{avama}\text{ days}}{25082580 \times 9} \text{ mins.}$$

$$= \frac{\textit{avama}\text{ days}}{9} \text{ signs} + \frac{\textit{avamaśeṣa}}{207} \text{ degrees}$$

$$- \frac{2172 \times 1800 \times 11}{25082580 \times 9 \times 2} \text{ mins. per year}$$

$$= \frac{\textit{avama}\text{ days}}{9} \text{ signs} + \frac{\textit{avamaśeṣa}}{207} \text{ degrees} - \frac{1}{10} \text{ min. per year}$$

since epoch.

Now the longitude of Moon's ascending node at the epoch (*Ahargoṇa* $=1384306$)

$$= 12 \text{ signs} - \left[6 \text{ signs} + \frac{232226 \times 13484806}{1577917500} \text{ revs.}\right]$$

$$= 12 \text{ signs} - [6 \text{ signs} + (6 + 24/9) \text{ signs} + 193']$$

$$= 12 \text{ signs} - [12 \text{ signs} + 24/9 \text{ signs} + 193']$$

$$= 12 \text{ signs} - [24/9 \text{ signs} + 193'], \text{ neglecting revolutions.}$$

Therefore,

Longitude of Moon's ascending node for the desired day

$$= 12 \text{ signs} - \frac{(avama \text{ days}) + 24}{9} \text{signs} - 193'$$

$$- \frac{avamaśeṣa}{207} \text{degrees} + \frac{1}{10} (\text{years elapsed since epoch}) \text{ minutes}$$

The rule in the text has 19′ in place of 193′.

THE *ŚAKĀBDA* CORRECTION

करणाब्दं गिरिरसशशि[१६७]सहितं प्रालेयदीधितेस्तत्त्वैः [२५] ।
उच्चस्य वेदरुद्रै[११४]र्भुजङ्गराजस्य रसरन्ध्रैः [९६] ॥१६॥
भूसूनोः शरवेदै[४५]र्बुधशीघ्रस्याम्बराश्विवारिधिभिः [४२०] ।
मुनिवेदै[४७]रिन्द्रगुरोः सितशीघ्रस्य त्रिबाणैकैः [१५३] ॥१७॥
सौरस्य नखै[२०]र्गुणयेच्छराग्नियुग्मैं[२३५]र्भजेच्च ता लिप्ताः ।
कुजशनिशशितनयेषु क्षेप्याः शेषेषु संशोध्याः ॥१८॥[1]

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1. *Cf. KK* (= *Khaṇḍa-khādyaka*), I, 3–5.

16-18. To the *Karaṇābda* (i. e., to the years elapsed since the epoch of the present *Karaṇa* work) add 167. Multiply the sum obtained, by 25 in the case of the Moon ; by 114 in the case of the Moon's apogee ; by 96 in the case of the Moon's ascending node ; by 45 in the case of Mars ; by 420 in the case of Mercury's *Śīghrocca* ; by 47 in the case of Jupiter ; by 153 in the case of Venus's *Śīghrocca* and by 20 in the case of Saturn ; and divide each product by 235. The resulting quotients, treated as minutes of arc, should be added to the mean longitude in the case of Mars, Saturn, and Mercury's *Śīghrocca* and subtracted from the mean longitude in the case of the remaining planets.[1]

The correction stated above is well known as the *Śakābda* correction, and occurs for the first time in the present work. This correction is supposed to have been zero in the beginning of the *Śaka* year 444 (=A. D. 522), and thereafter to have increased uniformly at the rate given in the following table :

Table 1. *Śakābda* correction per year

Planet	*Śakābda* correction per year	
Moon	−25/235	minutes of arc
Moon's apogee	−114/235	,,
Moon's ascending node	−96/235	,,
Mars	+45/235	,,
Mercury's *Śīghrocca*	+420/235	,,
Jupiter	−47/235	,,
Venus's *Śīghrocca*	−153/235	,,
Saturn	+20/235	,,

1. The same correction (but in different words) occurs in *Graha-cāra-nibandhana-saṁgraha* (=*GCNS*), vss. 17-18, written in 932 A. D.

THE *KALPA* CORRECTION

कल्पारम्भगतान् चतुर्युगगणान् गोपाद[३/४]केनाधिकान्[1]
लङ्का[१३]क्षेत्र[२६]दशास्य[१५८]ताम्र[२६]भुज[८४]
सद्[७]धाम[५९]क्लम[५३]घ्नान्[2] हरेत् ।
भागाद्याप्तफलं क्रमा[द्वि]ननुजै[८०६४]श्चन्द्राद् बुधारार्कि[3]युक्
[4]त्वन्योनं तु भटोपदेशजमिदं कात् पञ्चसिद्धान्तिनाम् ॥१९॥

19. Multiply the number of ***caturyugas*** **elapsed since the beginning of the (current)** ***Kalpa*****, as increased by 3/4, severally by 13, 26, 158, 26, 84, 7, 59, and 53 and divide (each product) by 8064 : the quotients obtained, in degrees etc., are the (*****Kalpa*****) corrections for the Moon etc. in the respective order. The corrections for Mercury's** ***Śīghrocca*****, Mars and Saturn are additive and those for the other planets are subtractive. This is based on the instruction of (Ārya)bhaṭa and is applicable to all the five** ***siddhāntas*** **beginning with the** ***Brahma-siddhānta*****.**

The *Kalpa* correction has not been found to occur in any other work so far. However, it has been referred to by the Kerala astronomer Parameśvara (A. D. 1431). In his commentary on the *Laghu-Bhāskarīya* (i. 37) of Bhāskara I, he writes :

"There are five corrections which are to be performed on the basis of time elapsed (since some particular epoch). They are :

Two *Bhaṭābda* corrections, *Nibandhokta* correction, *Kalpa* correction and *Manuyuga* correction.

One should perform that one which makes calculations tally with observation."

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1. A. गोपादवन्धाब्धिपान्
2. A. घान् for घ्नान्
3. A. क्ति for र्कि
4. A. त for त्व

The values per *yuga* of the *Kalpa* correction, as stated by Deva in the above stanza, are exhibited in the following table :

Table 2. *Kalpa* correction per *yuga*

Planet	*Kalpa* correction per *yuga*	
Moon	—13/8064	degrees
Moon's apogee	—26/8064	,,
Moon's ascending node	—158/8064	,,
Mars	+26/8064	,,
Mercury's *Śīghrocca*	+84/8064	,,
Jupiter	—7/8064	,,
Venus's *Śīghrocca*	—59/8064	,,
Saturn	+ 53/8064	,,

THE *MANUYUGA* CORRECTION

वस्वेकेषुयुगघ्नं [८, १, ५, ४] मनुयुगमर्कादिमध्यमचतुर्णाम् ।
धनमृणमृणमृणमथ कृति [२०] गुणितं चक्रेशभै
[१२, ११, २७] र्लब्धम् ॥२०॥

भौमाङ्गिरश्शनीनां देयमृणं देयमब्धिनन्द [४, ९] हृते ।
सितबुधयोर्हेयं देयं सप्त [७] हृतं बुधस्योक्तम् ॥२१॥

20-21. **Multiply the number of *yugas* elapsed since the beginning of the (current) *Manu* by 8, 1, 5 and 4, respectively, and (treating the products as minutes) apply them additively, subtractively, subtractively, and subtractively to the mean longitudes of the four planets beginning with the Sun (i. e., the Sun, the Moon, the Moon's apogee and the Moon's ascending node) in their respective order. Again, multiply the same (number of *yugas*) by 20 and divide (severally) by 12, 11, and 27 respectively and (treating the quotients as minutes) apply them additively, subtractively and**

additively to the mean longitudes of Mars, Jupiter and Saturn, respectively. Divide (the same product of the number of *yugas* elapsed and 20) by 4 and 9, respectively, and (treating the quotients as minutes) apply them subtractively and additively to the mean longitudes of the *Śīghroccas* of Venus and Mercury, respectively. In the case of the *Śīghrocca* of Mercury, multiplication by 7 is also prescribed.[1]

This *Manuyuga* correction is found to be discussed also by the Kerala astronomer Śaṅkaranārāyaṇa (A. D. 869) in his commentary on the *Laghu-Bhāskarīya* of Bhāskara I. Śaṅkaranārāyaṇa tells us that some people in his time ascribed this correction to Āryabhaṭa I.

The following table gives the values of this correction for the various planets, per *yuga* :

Table 3. *Manuyuga* correction per *yuga*

Planet	*Manuyuga* correction per *yuga*	
Sun	+8	minutes
Moon	--1	,,
Moon's apogee	—5	,,
Moon's ascending node	4	,,
Mars	+20/12	,,
Mercury's *Śīghrocca*	+140/9	,,
Jupiter	—20/11	,,
Venus's *Śīghrocca*	-1/4	,,
Saturn	- 20/27	,,

RSINE-DIFFERENCES (FOR R = 300)

दशभागज्या द्विशराः[५२] पञ्चाशद्[५०] वसुकृता[४८]
शिशखिश्रुतयः [४३] ।
सप्तत्रिंशत्[३७] त्रिंशद्[३०] द्वियमा[२२] लोकेन्दवः[१३]
पञ्च[५] ॥२२॥

1. Stanzas 20-21 have been quoted and explained by Śaṅkaranārāyaṇa in his commentary on *LBh* (= *Laghu-Bhāskarīya*), ii. 22.

22. **The Rsine-differences at the intervals of 10 degrees are : 52, 50, 48, 43, 37, 30, 22, 13 and 5 (minutes).**

RSINES (FOR R = 300′)

रामो नु[५२] रत्नाढ्य[१०२]नृमान्य[१५०]लुब्धको[१९३]
नागाग्र[२३०]निस्तार[२६०]खजाग्र[२८२]
माधुराः [२९५] ।
ज्ञानाङ्ग[३००]मित्यत्र नव प्रकीर्तिता
जीवा ह्ययनन्ता[६००]प्तफलैः समन्विताः ॥२३॥

23 **52, 102, 150, 193, 230, 260, 282, 295 and 300 (minutes) : these are stated to be the nine Rsines.**

To obtain the Rsine of an arc, divide it into smaller arcs of 600 minutes each and add the Rsine-differences corresponding to each of them.

RVERSED-SINES (FOR R = 300′)

मुनि[५]दिव्यो[१८]नभो[४०] नाथः [७०] सनको [१०७]
नैशिकाननः [१५०] ।
दुग्धको [१९८] देवरो [२४८] ऽनङ्ग [३००] इति ज्या
व्युत्क्रमोदिताः ॥२४॥

24. **5, 18, 40, 70, 107, 150, 198, 248 and 300 (minutes) : these are the Rversed-sines.**

The above-mentioned Rsines, Rsine-differences and Rversed-sines relate to the circle of radius 300 minutes. They may be exhibited in tabular form as follows :

Table 4. Rsines, Rsine-Differences and Rversed-sines

Arc	Rsine	Rsine–difference	Rversed-sine (=R – Rcosine)
600′	52′	52′	5′
1200′	102′	50′	18′
1800′	150′	48′	40′
2400′	193′	43′	70′
3000′	230′	37′	107′
3600′	260′	30′	150′
4200′	282′	22′	198′
4800′	295′	13′	248′
5400′	300′	5′	300′

EQUATION OF THE CENTRE FOR THE SUN AND MOON

स्वोच्चोनसूर्यशशिनो बाहुज्या खमनुभि[१४०]श्च षष्ट्या[६०] च ।

लब्धा भागाः शोध्या ह्युत्तरतो दक्षिणे देयाः ॥२५॥

भवतः स्फुटौ रवीन्दू

25-26(a). **Diminish the mean longitude of the Sun or Moon by that of its own apogee, and obtain the Rsine of the *bāhu* thereof. In the case of the Sun, divide that by 140 ; and in the case of the Moon, divide that by 60. The resulting degrees should be subtracted from the (respective) mean longitude (of the Sun or Moon) or added to that, according as the Sun or Moon is in the northern part (of the**

anomalistic sphere) or in the southern part. Thus are obtained the true longitudes of the Sun and the Moon.[1]

Let θ minutes be the mean anomaly of the Sun or Moon. Then using the epicycles of Āryabhaṭa I,

$$\text{Sun's equation of the centre} = \frac{R\sin\theta \times 3}{80} \text{ minutes } (R=3438')$$

$$= \frac{3438 \sin\theta \times 3}{80 \times 60} \text{ degrees}$$

$$= \frac{300 \sin\theta}{140} \text{ degrees approx.}$$

$$\text{Moon's equation of the centre} = \frac{R\sin\theta \times 7}{80} \text{ mins. } (R = 3438')$$

$$= \frac{3438 \sin\theta \times 7}{80 \times 60} \text{ degrees}$$

$$= \frac{300 \sin\theta}{60} \text{ degrees approx.}$$

BHUJĀVIVARA AND LONGITUDE CORRECTIONS FOR THE MOON

भगणाप्तं रविभुजाफलं शशिनि ।
रविवद्धनमृणमपरप्राच्योर्योजनचतुर्भागः ॥२६॥

26(b-d). **The Sun's equation of the centre (*bhujāphala*) divided by 27 (gives the Moon's *bhujāvivara* correction. This) should be applied to the Moon's longitude in the same way as the Sun's equation of the centre is applied (to the Sun's longitude).**[2]

One-fourth of the distance, in *yojanas*, of the local place from the prime meridian (is the longitude correction for the Moon. This) should be applied positively or negatively, according as the local place is to the west or to the east of the prime meridian.

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1. For similar rules see *ŚiDVṛ* (=*Śiṣya-dhīvṛddhida*), I, xiii. 4 (a-b).
2. *Cf. KK*, I, i. 18 (c-d). Also *cf. LBh*, ii. 5.

That is,

$$\text{Moon's } \textit{bhujāvivara} \text{ correction} = \frac{\text{Sun's } \textit{bhujāphala}}{27} \text{ minutes} \quad (1)$$

$$\text{Moon's longitude correction} = \frac{\text{local longitude in } \textit{yojanas}}{4} \text{ minutes.} \quad (2)$$

The rationale of these formulae is as follows :

Assuming the Moon's mean daily motion as equal to 791 minutes (*vide infra*, vs. 31) and the equatorial circumference of the Earth as 3299 *yojanas* (*vide infra*, vs. 33), we have

$$\text{Moon's } \textit{bhujāvivara} \text{ correction} = \frac{\text{Sun's } \textit{bhujāphala} \times 791}{21600} \text{ minutes}$$

$$= \frac{\text{Sun's } \textit{bhujāphala}}{27} \text{ minutes} \quad (1)$$

$$\text{Moon's longitude correction} = \frac{\text{local long. in } \textit{yojanas} \times 791}{3299} \text{ minutes}$$

$$= \frac{\text{local long. in } \textit{yojanas}}{4} \text{ minutes.} \quad (2)$$

The *bhujāvivara* correction for the Sun has been omitted here by the author. It is noteworthy that in the *Khaṇḍa-khādyaka* of Brahmagupta too the *bhuājvivara* correction for the Sun is omitted.

LONGITUDE CORRECTION : GENERAL RULE

देशान्तरघटीक्षुण्णा मध्या भुक्तिः खचारिणाम् ।
षष्ट्या भक्तं ऋणं प्राच्यां रेखायाः पश्चिमे धनम् ॥२७॥[1]

27. **The mean daily motion of a planet multiplied by the longitude (of the place) in terms of *ghaṭīs* and divided by 60 should be subtracted (from the longitude of the planet) (if the place is) to the east of the prime meridian and added (to the longitude of the planet) if the place is to the west of the prime meridian.**

1. Verse 27 is exactly the same as *LBh*, i. 31.

LOCAL LONGITUDE IN TIME

गणितप्रक्रियाप्राप्तप्रत्यक्षीकृतकालयोः ।
विश्लेषो ग्रहणे यः स्यात् कालो देशान्तरस्य सः ॥२८॥[1]

28. The difference between the computed and observed times of an eclipse is the longitude (of the place) in terms of time.

The computed time is the local time for the place lying at the intersection of the prime meridian and the local circle of latitude, while the observed time is the local time for the local place. The difference between the two is obviously the longitude in time for the local place.

It may be mentioned that in Hindu astronomy time is measured from sunrise.

LOCAL PLACE RELATIVE TO PRIME MERIDIAN

अतीत्य गणितानीतं यदा स्यातामुपप्लुती ।
पूर्वेण समरेखाया द्रष्टा स्यात् पश्चिमेऽन्यथा ॥२९॥[2]

29. If the (lunar and solar) eclipses occur after the calculated time, then the observer is to the east of the prime meridian ; otherwise, to the west.

The calculated time (as stated above) is the local time for the place lying at the intersection of the prime meridian and the local circle of latitude.

THE PRIME MERIDIAN

रेखा[देशाः] लङ्का स्वामीनगरं वत्साख्यभद्रपुरी ।
उज्जयिनी त्वथ मालवनगरं स्थानेश्वरं मेरुः ॥३०॥

30. (The following are the notable places on) the prime meridian ; ***Laṅkā, Svāmīnagara,*** **the excellent town of** ***Vātsyapura, Ujjayinī, Mālavanagara, Sthāneśvara*** **and** ***Meru.***

1. Verse 28 is almost exactly the same as *LBh*, i. 29.
2. Verse 29 is exactly the same as *LBh*, i. 30.

Laṅkā is the hypothetical place on the equator where the Hindu prime meridian is supposed to intersect it. Svāmī-nagara is Svāmīhallī (modern Samehalli) in Mysore, in latitude 15°N and longitude 76°.3E approx. Vātsyapura is Basim in Akola district (Mahārāṣṭra), about 70 km. south-south-east of Akola, in latitude 20°·05 N and longitude 77°·10 E. Mālava-nagara is Nagara or Karkoṭanagara in Tonk district in Rajasthan, lying abouts 35 km. to the south-south-east of Tonk. Sthāneśvara (or Sthāṇvīśvara) is a sacred place in Haryana, about two furlongs from the city of Thanesar (latitude 29°·58N, longitude 76°·56E). Meru is the north pole.

MEAN MOTIONS OF THE SUN AND MOON

भानोर्नवशर[५९]लिप्ता मध्यगतिः शशिनवस्वराः
[७९१] शशिनः ।

31(a-b). The mean daily motion of the Sun is 59 minutes : of the Moon, 791 minutes.

For the mean daily motions of the other planets, see *infra*, viii. 5.

TRUE MOTIONS OF THE SUN AND MOON

अथ वर्तमानजीवा स्वत्र्यंश[$\frac{1}{3}$]युता कलाश्चेन्दोः ॥३१॥
कृतयम[२४]भक्ता भानोर्मध्यमपदयोः स्वमध्यगतौ ।
क्षिप्त्वा त्यक्त्वाऽऽद्यन्ते स्फुटभुक्तिर्भवति रविशशिनोः ॥३२॥

31(c-d)-32. The current Rsine-difference increased by one-third of itself gives the minutes of the motion-correction for the Moon ; the same (current Rsine-difference) divided by 24, for the Sun. This being added to the mean daily motion in the second and third (anomalistic) quadrants and subtracted from the mean daily motion in the first and fourth (anomalistic) quadrants yields the true daily motion in the case of the Sun and the Moon.[1]

That is,

$$\text{Sun's motion-correction} = \frac{\text{current Rsine–difference}}{24} \text{ minutes} \qquad (1)$$

1. *Cf. ŚiDVr*, I, xiii. 4 (c-d).

Moon's motion–correction $= (1 + 1/3)$ (current Rsine–difference) minutes. ......(2)

The rationale of these formulae is as follows :

According to Āryabhaṭa I :

motion-correction

$$= \frac{\text{(current Rsine–difference)(mean daily motion) (epicycle).}}{\text{(elemental arc)} \times 80}$$

Therefore,

Sun's motion–correction $= \frac{\text{(current Rsine-difference)} \times 59 \times 3}{600 \times 80}$ where R = 3438′.

$= \frac{\text{(current Rsine-difference)} \times 59 \times 3}{600 \times 80 \times 300/3438}$, where R = 300′

$= \frac{\text{current Rsine-difference}}{24}$ minutes.

Moon's-motion–correction $= \frac{\text{(current Rsine-difference)} \times 791 \times 7}{600 \times 80}$, where R = 3438′

$= \frac{\text{(current Rsine-difference)} \times 791 \times 7}{600 \times 80 \times 300/3438}$, where R = 300′

$= \frac{\text{current Rsine-difference}}{3}$ minutes.

UJJAYINĪ FROM LAṄKĀ

नवनिधिदन्ता [३२९९] लङ्कावन्त्योर्मध्ये
कुपरिधिरष्ट्या [१६] प्ता ।

33(a-b). 3299 *(yojanas)* is the Earth's circumference ; this divided by 16 gives the distance between *Laṅkā* and *Avantī* (or *Ujjayinī*).[1]

EQUINOCTIAL MIDDAY SHADOW

स्याद् योजनं यदिष्टं तत्कुकृतै [४१] श्च विषुवच्छाया ।।३३।।

33(c-d) The distance, in *yojanas*, of any arbitrary place from *Laṅkā* when divided by 41 gives the equinoctial midday shadow for that place (in *aṅgulas*).[2]

1. *Cf. Ā* (= *Āryabhaṭīya*), iv. 14.
2. *Cf. VSi* (= *Vaṭeśvara-siddhānta*),III, i. 36. Vaṭeśvara takes 40 instead of 41.

This rule is based on the assumption that the equinoctial midday shadow at Ujjayinī is 5 *aṅgulas*. The proportion used is : When the equinoctial midday shadow of 5 *aṅgulas* corresponds to a distance of 3299/16 *yojanas* from Laṅkā, what equinoctial midday shadow in *aṅgulas* would correspond to the desired distance, in *yojanas*, from Laṅkā ? This yields the formula :

Desired equinoctial midday shadow

$$= \frac{5 \times (\text{distance in } yojanas \text{ from Laṅkā})}{3299/16} \ aṅgulas$$

$$= \frac{\text{distance in } yojanas \text{ from Laṅkā}}{41} \ aṅgulas.$$

ASCENSIONAL DIFFERENCES OF THE SIGNS

कृत[४]गुणविषुवच्छायाव्यङ्गुलयो रवि[१२]
शरेन्दु[१५]रसशिखिभिः [३६] ।
लब्धाश्चरजविनाड्यस्त्रिषु राशिष्वर्कशशिभुजयोः ॥३४॥

34. Multiply the *vyaṅgulas* of the equinoctial midday shadow by 4 and divide the product severally by 12, 15 and 36 : the quotients obtained are twice the ascensional differences, in *vināḍīs*, of the (first) three signs of the ecliptic (lit. relating to the longitude of the Sun and the Moon).[1]

That is,

ascensional difference of Aries $= \frac{1}{2} \cdot \frac{p \times 4}{12}$ or $\frac{p}{6}$ *vināḍīs*

ascensional difference of Taurus $= \frac{1}{2} \cdot \frac{p \times 4}{15}$ or $\frac{2p}{15}$ *vināḍīs*

ascensional difference of Gemini $= \frac{1}{2} \cdot \frac{p \times 4}{36}$ or $\frac{p}{18}$ *vināḍīs*,

where p is the equinoctial midday shadow in terms of *vyaṅgulas* (one *vyaṅgula* being equivalent to one-sixtieth of one *aṅgula*).

1. *Cf. PSi* (= *Pañca-Siddhāntikā*), iii. 10; *BrSpSi* (= *Brāhma-sphuṭa-siddhānta*), *Dhyānagrahopadeśādhyāya*, (xxv). 61; *KK*, I, iii. 1; *MBh*, iii. 8; *ŚiDVr*, I, xiii. 9; *VSi* III, vi. 26; *SiŚi*, I, ii. 50-51.

CONVERSION *OF ŚAKA* YEAR INTO *KALI* YEAR

नवशैलरूपवह्नीन् [३१७९] युक्त्वा शकाभिधानवर्षेषु ।
भवति गतं कलिवर्षं तस्मादयनं विजानीयात् ॥३५॥

35. Adding 3179 to the years of the socalled *Śaka* era, one gets the (elapsed) *Kali* years. From them one should compute the motion of the equinoxes (as follows) :

MOTION OF THE SOLSTICES OR EQUINOXES

कल्यब्दात्तिथिषड्भि[६१५]राप्तमयनं स्याद्राशिभागादिकं
तद्दोःक्रान्तिजलिप्तिका ऋणधनं स्याद् गोलतो भास्करे ।
सौम्याद् दक्षिणतः क्रमाद् दिनदलच्छायाविधौ सर्वदा
नान्यस्मिन् कुमुदाधिपस्य च तथा मध्यप्रभाया विधौ ॥३६॥[1]

36. Divide the elapsed *Kali* years by 615 : the result is the longitude of the *ayana-graha* (i. e., solstitial planet) in terms of signs, degrees, and so on. The declination, in terms of minutes, of that *ayana graha* (is the motion of the equinoxes. This) should be subtracted from or added to the longitude of the Sun, according as the Sun is in the northern or southern hemisphere. This correction should always be applied while computing the midday shadow, but in no other computation. This correction should be applied in the case of the Moon too while computing the Moon's meridian shadow.

That is,

$$\text{motion of the equinoxes} = \text{arc}\,\frac{\text{Rsin }(ayana\text{-}graha)\times\text{Rsin }24^\circ}{\text{R}},\ \text{R}=300',$$

where *ayana-graha* $= Y/615$ signs, and Y = number of *Kali* years elapsed.

The following rule which is almost the same as given above has been ascribed by Āmarāja to the *Khaṇḍa-Khādyakottara* of his teacher Trivikrama :

1. Verse 36 has been quoted by Parameśvara (A. D. 1431) in his commentary on *LBh*, ii. 16.

"Add 3179 to the (elapsed) *Śaka* years and divide the sum by 7380: the quotient gives (the longitude of the *ayana-graha* in terms of) revolutions, etc. The corresponding declination should be applied (to the longitude of a planet) negatively or positively according as it is north or south. This motion of the solstice (or equinox) should always be applied while calculating the Sun's declination, the Sun's ascensional difference, longitudes of the horizon–ecliptic and meridian–ecliptic points and in the computations relating to the visibility of the planets and the *pāta*."[1]

The following verse quoted by Āmarāja again gives the same correction :

> काले कलेः खवसुपावकशैल (7380) भक्ते स्यादायनं च भगणादि फलं ग्रहस्य ।
> तद्गोलयो ऋणधनं तद(थो चरांशक्रान्त्यं)शलग्नसमयानयने ग्रहाणाम् ॥[2]

The above correction is based on the assumption that the summer and winter solstices (and therefore the vernal and autumnal equinoxes) have an oscillatory motion of amplitude 24°, the period of one complete oscillation being 7380 years. The rate of motion of the equinoxes thus amounts to about 47″ per annum, the modern value being 50″ approximately.

THE DECLINATION TABLE

> प्रवर[२४२]धीसव[४७९]लीनसु[७०३]दीनधी[९०८]–
> जंहिनयं[१०८८]सगराय[१२३७]सभालयम्[१३४७] ।
> तटभयं[१४१६]नवभार्यं[१४४०]इति क्रमात्
> समुदिता विदुषाऽपमलिप्तिकाः ॥३७॥[3]

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1. गोऽगैकगुण 3179 युक्शा(कात्खाष्टवह्नि)नगै 7380 हृतात् ।
भगणादेः क्रान्तिभागा ऋणस्वं सौम्यदक्षिणाः ॥
अयमांशाः प्रदातव्या लग्ने क्रान्तौ चरा(गमे ।
विन्निभे स)न्निभे याते तथा दृक्कर्मपातयोः ॥
See Āmarāja's comm. on *KK*, iii. 11, p. 105.

2. See Āmarāja's comm. on *KK*, iii, 11, p. 106-7.

3. Viṣṇu Śarmā in his comm, on *Vidyā-Mādhavīya* (ii. 30) quotes the following verse giving slightly differing declinations :
गभीरनु [२४३] द्धींसवनी [४७६] वनार्थिनी [७०४] जने धनं [६०८]
धेहिनयं [१०८६] जगत्प्रिये [१२३८] ।
सभालये [१३४७] तापभयं [१४१६] नभोभयं [१४४०]
रवीन्दुबाहोर्दशभागजापमाः ॥

37. **The declinations (at the intervals of 10° of the ecliptic, starting from the first point of Aries) as stated by the learned astronomers are :**

242′, 479′, 703′, 908′, 1088′, 1237′, 1347′, 1416′ and 1440′ respectively.

Below we give the declinations at various points of the ecliptic as given by Brahmagupta, Deva and the author of the *Vākya-karaṇa* :

Table 5. Declinations at the intervals of 5°, 10°, or 15° on the ecliptic

Longitude	declination according to		
	KK (iii.7)	*KR*	*VāKa* (iii. 19a-20)
5°			122′
10°		242′	242′ (243′)
15°	362′		362′
20°		479′	478′ (479′)
25°			593′
30°	703′	703′	703′ (704′)
35°			809′
40°		908′	907′
45°	1002′		1002′
50°		1088′	1088′
55°			1167′
60°	1238′	1237′	1237′ (1238′)
65°			1298′ (1297′)
70°		1347′	1348′ (1347′)
75°	1388′		1388′
80°		1416′	1416′
85°			1434′ (1433′)
90°	1440′	1440′	1440′

Similar declination tables have been given by the other Hindu astronomers also. For example, Varāhamihira has given a table of declinations at the intervals of 7°30′.[1] Mallikārjuna Suri[2] (A.D. 1178) and Kṛṣṇa-daivajña[3] (A.D. 1653) have given declination tables at the intervals of 6°. Makaranda (c. A.D. 1478) gives a declination table at the intervals of one degree on the ecliptic as measured from the first point of Aries. See Makaranda's Table 39.

NORTHERN AND SOUTHERN HEMISPHERES (*GOLA*)

सर्वत्रोत्तरगोलो मेषादिर्दक्षिणस्तुलादिः स्यात् ।

38(a-b). Everywhere (in this work) the northern hemisphere (*uttaragola*) means the six signs beginning with the first point of Aries and the southern hemisphere (*dakṣiṇagola*) means the six signs beginning with the first point of Libra.

Bhaṭṭotpala writes :

"While the Sun is in the six signs beginning with Aries, it is the northern hemisphere; when it is in the six signs beginning with Libra, it is the southern hemisphere."[4]

LENGTHS OF DAY AND NIGHT

त्रिंशन्नाड्यः सचरा [दिवस]निशे चन्द्रस्य चेत् सैके ॥३८॥

38(c-d). 30 *nāḍīs* plus twice the ascensional difference is the length of day or night (according as the Sun is in the northern or southern hemisphere).[5] The same plus 1 is the length of day or night for the Moon.

In the case of the Moon's day and night, there is an addition of 1 *nāḍī*, because the Moon remains longer above the horizon or below the horizon for 1 *nāḍī*, since its own motion for 30 *nāḍīs* is equal to $791'/2 = 395'\cdot5$ or $6^\circ\cdot6$, which corresponds to 1 sidereal *nāḍī* approximately.

1. See *PSi*, iv. 17-18(a-b).
2. Quoted in his comm on *SūSi* (= *Sūrya-siddhānta*), xi. 14-15 from his *Gaṇakahitārtha*.
3. See *KKau* (= *Karaṇa-Kaustubha*), iv. 11.
4. See Bhaṭṭotpala's commentary on *KK*, I, i, 20.
5. *Cf*. *KK*, I, iii, 3.

CARA-CORRECTION

चरदलविनाडिकागतिकलावधात् खखरसाग्नि [३६००]-
लब्धकलाः ।
ऋणमुदयेऽस्तमये धनमुत्तरगोलेऽन्यथा याम्ये ॥३९॥[1]

39. **Multiply the Sun's ascensional difference in terms of *vināḍīs* by the (planet's) motion in terms of minutes and divide the product by 3600. The resulting minutes should be subtracted from the planet's longitude for sunrise or added to the planet's longitude for sunset when the Sun is in the northern hemisphere, and *vice versa* when the Sun is in the southern hemisphere.**

That is,
cara-correction=

$$\frac{(\text{Sun's asc. diff. in } \textit{vināḍīs}) \times (\text{planet's motion in minutes})}{3600} \text{ minutes.}$$

PLANET'S LONGITUDE FOR THE DESIRED TIME

धनमृणमेष्यातीते तात्कालिकहेतुकस्तु सर्वेषाम् ।
कालविनाडीर्हत्वा स्वगत्या खखरसाग्नि [३६००]भिर्लब्धाः ॥४०॥

40. **To obtain the instantaneous longitude in the case of all planets, the time (elapsed since or to elapse before sunrise), measured in terms of *vināḍīs*, should be multiplied by the planet's own (mean daily) motion (in minutes), and then (the product obtained should be) divided by 3600 : the resulting minutes should be added to or subtracted from the planet's longitude, according as sunrise has already occurred or is to occur.**

ELEMENTS OF THE *PAÑCĀṄGA*

1. *TITHI*

रविरहितशशांककला गगनाश्विस्वर [७२०]हृतास्तिथयः ।

1. Verse 39 is exacly the same as *BrSpSi*, xxv. 64 and *KK*, I, iii. 2

शेषं हित्वाऽधस्तात् षष्टिगुणं द्वयमथार्केन्द्वोः ।।४१।।
भुक्त्यन्तरेण भाज्यं लब्धं तिथिनाडिका गतैष्याः स्युः ।

41-42(a-b). Subtract the Sun's longitude from the Moon's longitude ; convert the difference into minutes and divide by 720 : the quotient gives the (number of) ***tithis*** **(elapsed). Set down the remainder and the remainder subtracted from 720 one below the other; and multiply both of them by 60 and divide by the motion-difference of the Sun and Moon. The quotients obtained give the** ***nāḍīs*** **elapsed and** ***nāḍīs*** **to elapse (of the current** ***tithi*****).**

LOCAL TIME

रविचरदलमुदक् क्षेप्यमथो दक्षिणे व्यस्तम् ।।४२।।

42(c-d). To find the time at the local place, add the (Sun's) ascensional difference to the time at the local equatorial place, provided the Sun is in the northern hemisphere; and subtract the same, when the Sun is in the southern hemisphere. (It is assumed that the local place is in the northern hemisphere.)

The time at the local equatorial place is obtained by applying the longitude correction to the time at Laṅkā. This correction is additive, if the local place is to the east of the prime meridian, and subtractive if the local place is to the west of the prime meridian.

2(a). SUN'S *NAKṢATRA*

कलितं रविमष्टशतैर्विभजेद्भान्यंशविरहितच्छेदात् ।
अंशाच्च षष्टिगुणितात् पुनरपि तैरेव घटिकाः स्युः ।।४३।।

43. Reduce the longitude of the Sun to minutes, and then divide by 800: the quotient gives the (number of) ***nakṣatras*** **passed over (by the Sun). Multiply the remainder and the divisor minus remainder (severally) by 60 and divide both of them by the Sun's daily motion: the results obtained give the** ***ghaṭīs*** **elapsed and the** ***ghaṭīs*** **to elapse (of the current** ***nakṣatra*****).**

The stars lying near the ecliptic are divided into 27 groups called *nakṣatras*. The names of these *nakṣatras*, in the order in which they occur, are as follows :

1.	Aśvinī	10.	Maghā	19.	Mūla
2.	Bharaṇī	11.	Pūrvā Phālgunī	20.	Pūrvāṣāḍha
3.	Kṛttikā	12.	Uttarā Phālgunī	21.	Uttarāṣāḍha
4.	Rohiṇī	13.	Hasta	22.	Śravaṇa
5.	Mṛgaśirā	14.	Citrā	23.	Dhaniṣṭhā
6.	Ārdrā	15.	Svātī	24.	Śatabhiṣak
7.	Punarvasu	16.	Viśākhā	25.	Pūṛva-Bhādrapada
8.	Puṣya	17.	Anurādhā	26.	Uttara-Bhādrapada
9.	Āśleṣā	18.	Jyeṣṭhā	27.	Revatī

The first *nakṣatra* is supposed to begin at the first point of the star Zeta Piscium.

Starting from the first point of the *nakṣatra* Aśvinī, the ecliptic is also divided into 27 equal parts, each of 800′. These divisions of the ecliptic are also called *nakṣatras* and given the same names as the twenty-seven *nakṣatras* mentioned above. The *nakṣatras* referred to in the above stanza are these 27 divisions of the ecliptic.

2(b). MOON'S *NAKṢATRA*

शशिनं कलितं विभजेच्छताष्टकैरागतानि भानि स्युः ।
शेषे गतभाविन्यो नाड्यस्तिथिवत् स्वभुक्तिहृते ॥४४॥

44. Reduce the Moon's longitude to minutes and then divide by 800: the quotient obtained gives the (number of) *nakṣatras* passed over (by the Moon). The remainder and the divisor minus remainder (multiplied by 60 and) divided by the (Moon's) own daily motion give the *nāḍīs* elapsed and *nāḍīs* to elapse (of the current *nakṣatra*), as in the case of the *tithi*.

3. *YOGA-NAKṢATRA* OR *YOGA*

शशिमित्रैक्यं कृत्वा हृत्वाऽष्टशतैस्तु योगभानि स्युः ।
शशिमित्रभुक्तियुत्या हृतशेषे नाडिका ज्ञेयाः ॥४५॥

45. Add the longitudes of the Sun and the Moon (and reduce the sum to minutes) and then divide that by 800: the quotient gives the (number of) *yoga-nakṣatras* **passed over. Divide the remainder and the divisor minus remainder by the sum of the daily motions of the Sun and Moon (in degrees): the results obtained give the** *nāḍīs* **elapsed and** *nāḍīs* **to elapse (of the current** *yoga***).**

The *yogas*, too, are 27 in number, and their names, in the order of their occurrence, are as follows :

1.	Viṣkambha	10.	Gaṇḍa	19.	Parigha
2.	Prīti	11.	Vṛddhi	20.	Śiva
3.	Āyuṣmān	12.	Dhruva	21.	Siddha
4.	Saubhāgya	13.	Vyāghāta	22.	Sādhya
5.	Śobhana	14.	Harṣaṇa	23.	Śubha
6.	Atigaṇḍa	15.	Vajra	24.	Śukla
7.	Sukarmā	16.	Siddhi	25.	Brahmā
8.	Dhṛti	17.	Vyatīpāta	26.	Indra
9.	Śūla	18.	Varīyān	27.	Vaidhṛta or Vaidhṛti

It should be noted that in calculating the *tithi*, *nakṣatra*, *yoga* and *karaṇa*, the precession of the equinoxes is not applied to the longitude of the Sun. But in calculating the *Vyatīpāta*, it is applied.

THE THREE *VYATĪPĀTAS*

सूर्येन्दुयोगे चक्रार्धे व्यतीपातोऽथ वैधृतः ।
चक्रे च मैत्रपर्यन्ते विज्ञेयः सार्पमस्तकः ॥४६॥[1]

46. When the sum of the (true) longitudes of the Sun and the Moon amounts to half a circle (i.e., 180°), the phenomenon is called (*Cakrārdha-Vyatīpāta* **or** *Lāṭa-***)** *Vyatīpāta***; when that sum amounts**

1. Verse 46 is exactly the same as *LBh*, ii. 29.

to a circle (i.e., 360°), the phenomenon is called *Vaidhṛta-(Vyatīpāta)*; and when that (sum) extends to the end of the *nakṣatra* Anurādhā (i.e., when that sum amounts to 7 signs 16° 40′), the phenomenon is called *Sārpamastaka* (-*Vyatīpāta*).

ASTROLOGICAL SIGNIFICANCE OF *VYATIPĀTA*

एष्यो धनं क्षपयति व्यतिपातयोगो
मृत्युं ददाति नियतं खलु वर्तमानः ।
सन्तापशोकभयबन्धवधानतीत-
स्तस्माद् दिनत्रयमिदं परिवर्जनीयम् ॥४७॥[1]

47. When the phenomenon of *Vyatipāta* is to happen (on the next day), it causes loss of wealth ; when it actually occurs (on the current day), it causes death ; and when it has already occurred on the previous day), it causes distress, grief, fear, imprisonment, or execution. So these three days are to be avoided (and no auspicious deed such as journey, marriage, etc. should be performed on these three days).

The instruction of the above stanza is based on the teaching of Varāhamihira in his *Vṛhadyātrā (or Yakṣyāśvamedhīya)*[2]. Other astronomers differ from the above view. Thus, according to the astrologer Śrīpati, only one day, on which the phenomenon of Vyatipāta actually accurs, is to be

1. Verse 47 is almost exactly the same as the following verse occurring in the *Bṛhadyātrā* (or *Yakṣyāśvamedhīya*) of Varāhamihira :

एष्यो धनं क्षयपति व्यतिपातयोगो मृत्युं ददाति नियतं खलु वर्तमानः ।
सन्तापशोकबधदैन्यभयान्यतीतस्तस्माद् दिनत्रयमपि प्रजिहीत विद्वान् ॥

See David Pingree's ed., App. B, Vs. 1. (p. 80).

एष्यो धनं क्षपयति व्यतिपातयोगो मृत्युं ददाति नियतं खलु वर्तमानः ।
सन्तापशोकबधदैन्यभयान्यतीतस्तस्माद् दिनत्रयमिदं परिवर्जनीयम् ॥

See David Pingree's ed., App. B, vs. 11 (p. 81).

Verse 47, with slight variation, is also found to be quoted by Viṣṇu Śarmā in his commentary on *Vidyā-Mādhavīya*, ii. 31.

2. See David Pingree's ed., App. B, vss. 1 and 11.

avoided for auspicious work, not three days as prescribed above. According to some astronomers, only three *ghaṭīs* (instead of three days) are to be avoided.

The phenomenon of Vyatipāta is paid special importance in South India only. In North India, astronomers attach special importance to the *karaṇa* Viṣṭi, which they call Bhadrā, and do not prescribe any auspicious deed when it happens to occur.

CALCULATION OF *VYATIPĀTA*

DECLINATION

सूर्यचन्द्रमसोर्गोलं ज्ञात्वा लिप्तीकृतावम् ।
अनन्तेन[1] [६००] हरेल्लब्धं तयोर्वाक्यप्रमा भवेत् ॥४८॥
तद्वाक्ये पृथगेवात्र स्थापयेच्छेषमिश्रिते ।

48-49(a-b). In the case of the Sun and Moon, having determined its distance from the first point of Aries or Libra, (whichever is nearer), reduce it to minutes and divide by 600: the quotient gives the serial number of the tabular declination (crossed). Set down that declination in a separate place, and add to it the declination-difference corresponding to the remainder of the division. (This sum is the desired declination.)

THE DECLINATION TABLE

प्रभारत्नं [२४२] धीसवनं [४७९] गानस्थानं [७०३]
जने धनम् [९०८] ॥४९॥
देहि नित्यं [१०८८] सुगुप्रायः [१२३७] सर्वलोकं [१३४७]
तटिद्वपुः [१४१६] ।

1. It may be noted that word अनन्त has been used for 600 in *Grahacāra-nibandhana* (i, 22) and also in *Grahacāranibandhana-saṅgraha* (vs. 8). Also see *infra*, vs. 56.

नव वाक्ये[१४४०]ति वाक्यानि प्रोक्तानि रविसोमयोः ॥५०॥

49(c-d)-50. 242′, 479′, 703′, 908′, 1088′, 1237′, 1347′, 1416′ and 1440′ — these are stated to be the declinations (at the intervals of 10 degrees of the ecliptic, from the first point of Aries) for the Sun and Moon.[1]

This is the repetition of what has already been stated in verse 37 above.

MOON'S LATITUDE

भूयो हीनतमश्चन्द्रगोलवित्तमसः कलाम् ।
कृत्वा पूर्वविधानेन वाक्यान्येतानि चिन्तयेत् ॥५१॥

51. Now, subtract the longitude of the Moon's ascending node from the longitude of the Moon and reduce the resulting distance (of the Moon) from the Moon's ascending node to minutes. Then (dividing it by 600)[2] **find, as before, the serial number of the Moon's tabular latitude crossed. Then make use of the following table of latitudes.**

TABLE OF MOON'S LATITUDES

सवनानि[४७]प्रधानानि[९२]शालायां[१३५]
वासुकी[१७४]ननु ।
सेना राज्ञो[२०७]भृगुप्रायो[२३४]वामश्री[२५४]
श्चतुरो[२६६]ऽसुरः[२७०] ॥५२॥[3]

1. The literal translation is as follows :
"*Prabhāratnam*(=242), *Dhīsavanam*(=479), *Gānasthānam*(=703), *Janedhanam*(=908), *Dehi-nityam*(=1088), *Suguprāyaḥ*(=1237), *Sarvalokam*(=1347), *Taṭidvapuḥ*(=1416) and *Navavākya*(=1440) — these are the (declination) sentences for the Sun and the Moon."

2. व्यतीपाते तु त्रिज्ययैव हृत्वाऽऽनेयः, न द्वितीयस्फुटकर्णेन । See Nīlakaṇṭha's comm. on *Candracchāyāgaṇita*, vs. 2.

3. Also see *Mahāpātādhyāya*, vs. 37. Viṣṇu Śarmā, in his comm. on *Vidyā-mādhavīya*, ch. ñ, vs. 30, quotes the following verse :
सर्वज्ञ (४७) बुधा न (९३) शालिकां (१३५) वासाय (१७४) सुनारि (२०७) वागुराम् (२३४) ।
भूमीन्द्र (२५४) ततश्री (२६६) नः सुखं (२७०) दोः क्षेपकला दशांशजाः ॥

52. 47′, 92′, 135′, 174′, 207′, 234′, 254′, 266′ and 270′—(these are the Moon's latitudes at the successive intervals of 10° from the Moon's ascending node).

These may be exhibited in the tabular form as follows:

Table 6. Moon's latitudes at the successive distances of 10° from the Moon's ascending node.

Moon minus Moon's asc. node	latitude
10°	47′
20°	92′
30°	135′
40°	174′
50°	207′
60°	234′
70°	254′
80°	266′
90°	270′

Mallikārjuna Sūri (A. D. 1178), in his commentary on the *Sūrya-siddhānta* (xi. 14-15), quotes another list of Moon's latitudes at the successive intervals of 10°, from his own work *Gaṇaka-hitārtha*. This list has 173′ in place of 174′ ; otherwise it is the same as the above one. Viṣṇu Śarmā (c. A. D. 1363), in his commentary on the *Vidyā-Mādhavīya* (ii. 30), quotes a similar list of the Moon's latitudes at the successive intervals of 10°.[1] This list has 93′ in place of 92′ ; otherwise it is exactly the same as the above one, given by Deva. Makaranda (c. A. D. 1478) gives the Moon's latitude to 2 decimal places for every degree of the ecliptic as measured from the Moon's ascending node. See Makaranda's Table 40.

1. See foot-note 3 on p. 35 above.

MOON'S TRUE DECLINATION

एतास्तात्कालिका गोले समभिन्ने युतायुताः ।
चन्द्रस्य स्थानिके मध्ये तदा चान्द्रं फलं स्फुटम् ॥५३॥

53. The instantaneous latitude of the Moon added to or subtracted from the declination of the Moon's projection on the ecliptic, according as the two are of like or unlike directions, gives the true declination of the Moon.

TIME OF VYATIPĀTA

रविक्रान्तेर्भुजाच्चन्द्रो महांश्चेत्स गतो ध्रुवम् ।
अल्पः कोटिशशी तद्वद्विपरीते विपर्ययः ॥५४॥

यदा समानता क्रान्त्योः सूर्यचन्द्रमसोस्तदा ।
चक्रार्धं तद्विनिर्दिष्टं सर्वकार्यविगर्हितम् ॥५५॥

यदा विषमता क्रान्त्योः विवरेण तयोस्तदा ।
अनन्तं [६००] गुणयेत्पूर्ववाक्यहीनेतरेण तु ॥५६॥

हृत्वा लब्धकलाभिस्तु गतैष्ये हीनयुक् शशी ।
पुनर्गोलं परिज्ञाय स्फुटेद्यावत्समं भवेत् ॥५७॥

54-57. When the *bhujā* of the Moon's longitude is greater than the *bhujā* of the longitude corresponding to the Sun's declination, (it should be understood that) the phenomenon of *Vyatipāta* has already occurred. So is also the case when the *koṭi* of the Moon's longitude is less than the *koṭi* of the longitude corresponding to to the Sun's declination. In the contrary case, it is just the reverse (i.e., it should be understood that the phenomenon of *Vyatipāta* is to occur).

When there is equality of the Sun's and Moon's declinations, (both in magnitude and direction) then the *Vyatipāta* is called

Cakrārdha (or *Lāṭa Vyatipāta*). It is prohibited for all (auspicious) deeds.

When the declinations of the Sun and Moon are unequal, multiply 600 by their difference and divide (the product) by the succeeding tabular declination minus the preceding tabular declination (see vss. 49-50) and subtract the (resulting) quotient from or add that to the Moon's longitude, according as the *Vyatipāta* has occurred or is to occur. Again calculate the Moon's declination and iterate the process until the decinations (of the Sun and Moon) become equal.

For further details regarding *Vyatipāta* (also called *Pāta* or *Māhāpata*), see Appendix 1, *Mahāpātādhyāya*.

4. *KARAṆA*

1 MOVABLE *KARAṆAS*

व्यर्केन्दुकला भक्ताः खरसगुणै[३६०]र्लब्धमूनमेकेन ।
चलकरणानि बवादीन्यग[७]हृतशेषे तिथिवदन्यत् ॥५८॥

58. **The longitude of the Moon minus the longitude of the Sun should be reduced to minutes and then divided by 360. The (resulting) quotient should be diminished by 1 and then divided by 7. The remainder, counted from** *Bava*, **gives the (number of) movable** *Karaṇas* **(passed). To find the rest (i. e., the** *ghaṭīs* **elapsed of the current** *Karaṇa* **or** *ghaṭīs* **to elapse before the beginning of the next** *Karaṇa*), **one should proceed as in the case of the** *tithi*.

2. IMMOVABLE *KARAṆAS*

कृष्णचतुर्दश्यन्ते शकुनिः पर्वणि चतुष्पदं प्रथमे ।
तिथ्यर्धेऽन्त्ये नागं किंस्तुघ्नं प्रतिपदाद्यर्धे ॥५९॥[1]

59. **(Of the four immovable** *Karaṇas*) *Śakuni* **occurs in the second half of the 14th** *tithi* **in the dark half of the month ;** *Catuṣpada* **occurs in the first half and** *Nāga* **in the second half of the new**

1. Verses 58 and 59 are exactly the same as *KK*, I, i. 24 and 23 respectively.

moon *tithi* ; *Kiṁstughna* in the first half of the first *tithi* (in the light half of the month).

Śakuni, Catuṣpada, Nāga and *Kiṁstughna* are called immovable *Karaṇas* because their positions are fixed with respect to the *tithis. Śakuni* is a hawk; *Catuṣpada* is a quadruped ; *Nāga* is a serpent ; and *Kiṁstughna* is an animal. Their lords are *Kaliyuga,* Rudra, serpents and wind respectively.

The seven movable *Karaṇas*, in the order in which they occur, along with their lords, are as follows ;

Table 7. Movable *karaṇas* and their lords

	movable *Karaṇa*	Lord
1.	*Bava* or *Baba* (= lion ; *Babara* in Hindi)	Indra
2.	*Bālava* (=tiger)	Dhātā
3.	*Kaulava* (= boar. Derived from *Kola*, meaning boar)	Mitra
4.	*Taitila* (= donkey)	Aryamā
5.	*Gara* or *Gaja* (=elephant)	Earth
6.	*Vaṇij* or *Vaṇik* (=businessman)	Lakṣmī
7.	*Viṣṭi* or *Bhadrā* (= cow)	Yama

This cycle of the seven movable *Karaṇas* starts from the second half of the first *tithi* in the light half of the month and repeats itself eight times, whereafter the four immovable *Karaṇas* occur.

As pointed out above, the movable *Karaṇa* Viṣṭi or Bhadrā is considered highly inauspicious ; and is prohibited for all auspicious deeds, particularly in Northern India.

EQUALISATION OF LONGITUDES OF SUN AND MOON

एष्यश्च नाडीः पर्वणि रवौ क्षिपेत् प्रतिपदि त्यजेत्तु गताः ।
शशिनः स-कलाः सदृशौ चक्रार्धयुतश्च पौर्णमासीनः ॥६०॥

60. On a new moon day, one should add (as many minutes) to the Sun's longitude (for sunrise) (as there are) *nāḍīs* to elapse (before new moon) and on the next *tithi* (*pratipad*) one should subtract (as many minutes) from the Moon's longitude (for sunrise) (as there are) *nāḍīs* elapsed (since new moon). To the Moon's longitude (for sunrise), the minutes (of the difference between the longitudes of Sun and Moon) should also be added (in the former case) and subtracted (in the latter). Thus the longitudes of the Sun and the Moon become equal up to minutes.

In the case of the full moon *tithi*, the longitude of the Moon should be further increased by 6 signs.[1]

That is, if S and M denote the longitudes of the Sun and the Moon for sunrise on the new moon *tithi* and n the *nāḍīs* to elapse at sunrise before the end of the new moon *tithi*, then

Sun's longitude at the end of the new moon *tithi* (*amānta*)

$$=S+n \text{ minutes}$$

and Moon's longitude at the end of the new moon *tithi* (*amānta*)

$$=M+n \text{ minutes } +(S-M).$$

If S' and M' denote the longitudes of the Sun and the Moon for sunrise on the next *tithi*, and n' the *nāḍīs* elapsed at sunrise since the end of the new moon *tithi*, then

Sun's longitude at the end of the new moon *tithi*

$$=S'-n' \text{ minutes}$$

and Moon's longitude at the end of the new moon *tithi*

$$=M'-n' \text{ minutes } -(M'-S').$$

Similarly, if S and M denote the longitudes of the Sun and the Moon for sunrise on the full moon *tithi* (*pūrṇimā*), and n denote the *nāḍīs* to elapse at sunrise before the end of the full moon *tithi*, then

Sun's longitude at the end of the full moon *tithi* (*pūrṇimānta*)

$$=S+n \text{ minutes}$$

1. This rule is exactly the same as given in *LBh*, iv. 1.

and Moon's longitude at the end of the full moon *tithi*

$$=M+n \text{ minutes}+(S-M+6 \text{ signs}).$$

If S' and M' denote the longitudes of the Sun and the Moon for sunrise on the next *tithi*, and n' the *nāḍīs* elapsed at sunrise since the end of the full moon *tithi*, then

Sun's longitude at the end of the full moon *tithi*

$$=S'-n' \text{ minutes}$$

and Moon's longitude at the end of the full moon *tithi*

$$=M'-n' \text{ minutes}-\{M'-(S'+6 \text{ signs})\}.$$

For further details, see my notes on *LBh*, iv. 1.

SYNOPSIS

अधिमासावमरात्रवासरेशद्युगणार्केन्दुतदुच्चराहुजीवाः ।
परिमाणं द्युनिशोरिहाह देवस्तिथिभच्छेदसमानलिप्तिकाश्च ।।६१।।

61. The topics dealt with in this chapter by Deva are: Intercalary months, omitted lunar days, lord of the day, *Ahargaṇa*, longitudes of Sun, Moon, Moon's apogee and Moon's ascending node, the Rsines (for R = 300′), the measures of day and night, the ending moments of *tithi* and *nakṣatra*, and equalisation of the longitudes of Sun and Moon up to minutes.

इति करणरत्ने प्रथमोऽध्यायः ।

Thus ends Chapter One of the *Karaṇa-ratna*.

CHAPTER 2

THE LUNAR ECLIPSE

INVOCATION AND INTRODUCTION

षोडशसहस्रवनिताकुचघटघनघट्टितोऽपि यद्वक्षः ।
त्यजति न लक्ष्मीस्तमहं प्रणम्य वक्ष्ये शशिग्रहणम् ॥१॥

1. **Having bowed to Him whose bosom is not forsaken by *Lakṣmī* although it is heavily bruised by the pitcherlike breasts of sixteen thousand women, I proceed to explain the lunar eclipse.**

Obeisance is made here to Lord Kṛṣṇa who is said to have 16000 spouses according to Hindu mythology.

ANGULAR DIAMETERS OF SUN, MOON AND *RĀHU*

दश[१०]गुणितेन्दोर्भुक्तिः शशिशरयम[२५१]
भाजिता निजं बिम्बम् ।
नवनवभिः[९९] स्वा राहोस्तथा रवेः स्वा पुराणेन[१८] ॥२॥

2. **Ten times the Moon's daily motion when divided by 251 gives the Moon's own diameter and when divided by 99 gives the diameter of *Rāhu* (i.e., Shadow); and 10 times the Sun's daily motion when divided by 18 gives the diameter of the Sun.**[1]

That is,

$$\text{Sun's diameter} = \frac{10\times \text{Sun's daily motion}}{18} \text{ mins.}$$

$$\text{Moon's diameter} = \frac{10\times \text{Moon's daily motion}}{251} \text{ mins.}$$

1. Similar rules occur in *Grahaṇāṣṭaka*, vs. 1 (c-d). Also see *KK*, I, iv. 2(a-b).

$$Rāhu\text{'s diameter} = \frac{10 \times \text{Moon's daily motion}}{99} \text{ mins.}$$

For the rationale of these formulae, see my notes on *MBh* (=*Mahā-Bhāskarīya*), v. 6-7.

MOON'S LATITUDE

फणिरहितसमकलेन्दोर्ज्या स्वदशांशोनिताऽत्र विक्षेपः ।

3(a-b). From the longitude of the Moon at full Moon subtract the longitude of the Moon's ascending node. The Rsine of that diminished by one-tenth of itself is the Moon's latitude (at full moon).[1]

That is,

$$\text{Moon's latitude} = \frac{300 \sin (M-N) \times 270}{300} \text{ mins.}$$

$$= (1-1/10) \times R \sin (M-N) \text{ mins.},$$

where M and N are the longitudes of the Moon and the Moon's ascending node and $R=300'$.

TIMES OF FIRST AND LAST CONTACTS

तत्कृतिरहिते फणिशशिबिम्बसमासार्धवर्गे स्यात् ॥३॥

मूलं स्थित्यर्धकला रविशशिभुक्त्यन्तरोद्धृता नाड्यः ।

पर्वणि तद्रहिते स्यात् प्रग्रहणं तत्र संयुते मोक्षः ॥४॥

प्रतिपदि विपरीतमिदं त्वविशिष्टं जायते ग्रहणमध्यम् ।

सूर्यग्रहणेऽप्येवं राहुस्थाने तु शशिबिम्बम् ॥५॥

1. *Cf. KK*, I, iv. 1 (c-d); *ŚiDVr*, I, xiii. 10 (c-d).

3(c-d)-5. Subtract the square of that (Moon's latitude) from the square of half the sum of the diameters of the Moon and Shadow. The square root of that is half the duration of the eclipse in terms of minutes. This divided by the motion-difference of the Sun and Moon (in terms of degrees) gives the *nāḍīs* (of half the duration of the eclipse). (When the time is measured from sunrise) on the full moon *tithi*, these *nāḍīs* being subtracted from the time of opposition (of the Sun and Moon), the result is the time of the first contact; and the same *nāḍīs* being added to the time of opposition, the result is the time of the last contact. (When the time is measured from sunrise) on the next *tithi* (called *Pratipad*), the process is just the reverse. (That is, the time of the last contact is obtained by subtracting the above *ghaṭīs* from the time of opposition and the time of the first contact is obtained by adding those *ghaṭīs* to the time of opposition). The time of the middle of the eclipse is obtained by iterating the above process. In the case of a solar eclipse, the process is the same, except for that in the place of *Rāhu* (Shadow) one has to use the Moon's disc.

If D_1 and D_2 denote the diameters of the Moon and Shadow, and β the Moon's latitude for the time of opposition, then

$$\text{half the duration of the eclipse} = \sqrt{\left(\frac{D_1+D_2}{2}\right)^2-\beta^2}$$

$$= \frac{\sqrt{\left(\frac{D_1+D_2}{2}\right)^2-\beta^2}}{\text{motion diff. in degrees}}\ ghaṭīs$$

$$= G\ ghaṭīs, \text{ say.}$$

Therefore, measuring the time from sunrise on the full moon *tithi*,

time of first contact = time of opposition $-$ G *ghaṭīs*,

and time of last contact = time of opposition $+$ G *ghaṭīs*.

In order to obtain the time of the middle of the eclipse one has to obtain the true semi-durations of the eclipse by applying the process of iteration (*vide infra*, vss. 10-11(a–b)). If S_1 denotes the duration of the first part of the eclipse (from first contact to opposition) and S_2 the duration

of the second part of the eclipse (from opposition to the last contact), then

time of the middle of the eclipse = time of opposition $-(S_1-S_2)/2$.

For practical purposes, however, the time of opposition itself is taken as the time of the middle of the lunar eclipse.

POSSIBILITY OF A LUNAR ECLIPSE

सम्पर्कार्धादल्पे विक्षेपे ग्रहणमस्ति नास्त्यधिके ।
राहोर्युतिश्च दृष्टिर्यदा रवेः स्यात् तदा भवति ॥६॥

6. When the Moon's latitude (for the time of opposition) is less than half the sum of the diameters of the eclipsed and eclipsing bodies, an eclipse (of the Moon) is possible; when greater (or equal), it is not possible.

The conjunction of *Rāhu* (Shadow) with the Moon occurs when the Sun sees the Moon (i.e., when the Moon is diametrically opposite to the Sun).

Let D_1 be the diameter of the Moon, D_2 the diameter of the Shadow, and β the Moon's latitude, for the time of opposition. Then a lunar eclipse is possible when

$$\beta < \tfrac{1}{2}(D_1 + D_2),$$

and impossible when

$$\beta \geqslant \tfrac{1}{2}(D_1 + D_2).$$

PREDICTION OF AN ECLIPSE

द्वादशभागादूनं ग्रहणं तैक्ष्ण्याद्रवेरनादेश्यम् ।
षोडशभागादिन्दोः स्वच्छत्वादधिकमादेश्यम् ॥७॥[1]

7. A solar eclipse should not be predicted when it amounts to less than one-twelfth of the Sun's diameter (as it might not be visible to the naked eye) on account of the brilliancy of the Sun. But a lunar eclipse must be declared whenever it amounts to more than one-sixteenth of the Moon's diameter, as it will be visible (to the naked eye) on account of the transparency of the Moon.

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1. Verse 7 is exactly the same as *KK*, II, iv. 18, *BrSpSi*, v. 20 or *BrSpSi*, xxv. 20.

This instruction is against the teaching of Āryabhaṭa I.[1] The author of the present work follows Brahmagupta here and has deliberately adopted his verse verbatim.

DURATION OF TOTALITY

विक्षेपकृतिं त्यक्त्वा फणिशशिविष्कम्भविवरदलवर्गात् ।
मूलं भुक्त्यन्तरहृतमथ घटिकाः स्युर्विमर्दार्धे ॥८॥

8. **Subtract the square of the Moon's latitude (for the time of opposition) from the square of half the difference between the diameters of the eclipsed and eclipsing bodies and take the square root thereof, and then divide (that square root) by the motion-difference (of the Sun and Moon) (in terms of degrees): the quotient gives the *ghaṭikās* of half the duration of total eclipse.**

That is,

$$\text{half the duration of total eclipse} = \frac{\sqrt{\left(\frac{D_1 - D_2}{2}\right)^2 - \beta^2}}{\text{motion-difference in degrees}} \ \textit{ghaṭīs}.$$

MOON'S LATITUDE FOR FIRST OR LAST CONTACT

स्थितिदलघटिकासदृशी संख्या विषमे पदे स्वविक्षेपे ।
स्पर्शे शोध्या क्षेप्या समेऽन्यथा मोक्षकाले स्यात् ॥९॥

9. **(In order to obtain the Moon's latitude) for the first contact, subtract as many minutes from the Moon's latitude (for the time of opposition) as there are *ghaṭīs* in half the duration of the eclipse if the eclipse occurs in an odd nodal quadrant, and add the same number of minutes if the eclipse occurs in an even nodal quadrant. (In order to find the Moon's latitude) for the last contact, proceed reversely.**

Let the semi-duration of the eclipse be g *ghaṭīs*. Then Moon's latitude for the first contact = Moon's latitude at opposition $\mp g$ minutes, the minus

1. See *Ā*, iv. 47.

or plus sign being taken according as the eclipse takes place in an odd or even nodal quadrant.

Rationale. In g *ghaṭīs*, Moon's motion relative to Shadow

$$= \frac{(791-59)g}{60} \text{mins.}$$

$$= \frac{732}{60} g = 12{\cdot}2\ g \text{ mins.}$$

$$300 \sin (12{\cdot}2g) = \frac{300 \times 12{\cdot}2g}{3438}.$$

$$\text{Corresponding latitude-difference} = \frac{300 \times 12{\cdot}2g}{3438} \times \frac{9}{10} \text{mins.}$$

$$= \frac{3294\ g}{3438} \text{ mins.}$$

$$= g \text{ mins. approx.}$$

SEMI-DURATION OF ECLIPSE BY ITERATION

कृत्वाऽविशेषमेवं यावद् द्वितुल्यरूपता भवति ।
स्थितिदलविक्षेपौ तौ पुनः पुनः तावदानीयात् ॥१०॥
तेनानीतस्थितिदलघटिकाकालौ तु तौ स्फुटौ ज्ञेयौ ।

10-11(a-b). Having done this, apply the process of iteration in the following way: Calculate the semi-durations of the eclipse and the Moon's latitude (for the first and last contacts) again and again until the successive values are the same. The times, in *ghaṭīs*, of the semi-durations of the eclipse calculated from them (i.e., from the Moon's latitudes for the first and last contacts, obtained by iteration) are the true values of the two (semi-durations).

GRAPHICAL REPRESENTATION OF AN ECLIPSE

शशिरविवृत्तं लेख्यं स्फुटबिम्बदलेन दिक्चतुष्टयवत् ॥११॥

11(c-d). With half the diameter of the Moon (in the case of a lunar eclipse) or with half the diameter of the Sun (in the case of a solar eclipse), draw a circle, and furnish it with the four cardinal points.

प्रग्रहणमुक्तिवलने प्रागपरां तन्नयेत् परिधौ ।
अन्यदिशीन्दोरर्कग्रहणे परपूर्वयोः समानदिशि ॥१२॥

12. **In the case of a lunar eclipse, lay off the resultant *valanas*[1] for the first and last contacts towards the east and west respectively along the circumference in the opposite direction[2] (i.e., towards the north or south according as the *valana* is of south or north direction); and in the case of a solar eclipse, towards the west and east respectively in its own direction (north or south). (And set down points there).**

तत्र रवीन्द्वोर्वाच्यौ स्पर्शविमोक्षप्रदेशौ तौ ।
तद्द्विप्रदेशमध्यादारभ्येन्द्वर्कपरिधिमध्यगता ॥१३॥

13. **These points should be declared as the points of the first and last contacts of the Moon (in the case of a lunar eclipse) or of the Sun (in the case of a solar eclipse). Then draw lines proceeding from these two points and reaching the centre of the circle representing the Moon or Sun.**

रेखा चोत्तरदक्षिणसमदिक्स्था संविधेयेन्दोः ।
तत्रान्यद्दिशि न्यसेन्मध्याद्विक्षेपमात्मदिशि भानोः ॥१४॥

14. **Also draw another line joining the north and south cardinal points. Starting from the centre, lay off along this line the Moon's latitude (for the middle of the eclipse) in the contrary direction in the case of the Moon, and in its own direction in the case of the Sun.**

कृत्वाऽत्राङ्कं भ्रमयेद् ग्राहकबिम्बार्धसदृशसूत्रेण ।
छन्नपतिते रवीन्द्वोर्यथा यथाच्छेदिते प्रदृश्येते ॥१५॥
नभसि च तथा तथा ते भवतः संलक्षिते ग्रहणे ।

15-16(a-b). **Put down a point there. Taking it as centre and the semi-diameter of the eclipsing body as radius draw a circle by revolving**

1. For the *vikṣepa-valana*, *ayana-valana* and *akṣa-valana* and their resultant, see infra iii. 11-16.
2. In fact, only the *vikṣepa-valana* should be of the opposite directions; the other two *valanas* should be of their own directions.

the compass. As is a portion of the Sun or Moon seen intercepted by the eclipsing body in the diagram, just so is the (actual) Sun or Moon seen eclipsed in the sky during the eclipse.

It will be noted that the *valana* for the middle of the eclipse has been neglected and has not been laid off in the figure.

PATH OF THE ECLIPSING BODY

बिम्बद्वययुतिदलसमसूत्रं प्रागपरतो नयेन्मध्यात् ॥१६॥

प्रग्रहणमोक्षबिन्दू, स्पर्शत्वाङ्कौ तदग्रस्थौ ।
अङ्कत्रयद्विमत्स्यान्मुखपुच्छस्पृक्सूत्रसङ्गमे न्यस्य ॥१७॥

सूत्रात् त्रितयाङ्कस्पृग्रेखा या ग्राहको मार्गः ।
सहितबिम्बार्धसम्मितसूत्राग्रं मध्यबिन्दुतः प्राग्वत् ॥१८॥

ग्राहकमार्गं यत्र स्पृशति तमस्तत्र परिलेख्यम् ।
परिलेख्यमानमेतच्छशिपरिधिं यत्र संस्पृशेत्तत्र ॥१९॥

संच्छादितौ प्रदेशौ पश्चादेवं प्रदृश्येते ।

16(c-d)-20(a-b). From the centre (of the circle) draw two lines, each equal to half the sum of the diameters of the eclipsed and eclipsing bodies, towards the east and west, one towards the point of the first contact and the other towards the point of the last contact. The extremities of these lines are the points (denoting the positions of the centre of the eclipsing body at the times) of the first and last contacts. (The point at the extremity of the Moon's latitude for the middle of the eclipse is the third point). Now with the help of these three points construct two fish-figures, and keeping one end of a thread at the intersection of the head and tail lines of the two fish-figures, draw a circular arc (lit. line) through the above three points: this is the path of the eclipsing body. Now take a thread of length equal to half the sum of the diameters of the eclipsed and eclipsing bodies, and stretch it from the centre (of the circle towards the east and west), as before. Where the other extremity

of this thread meets the path of the eclipsing body (towards the east or west), taking that as centre draw a circle with radius equal to that of the Shadow. The point where this circle touches the circumference of the Moon, there lies the point of the first or last contact. This is how the points of the first and last contacts are seen afterwards (in the sky).

OBSCURATION AT THE GIVEN TIME (*IṢṬA-GRĀSA*)

इष्टघटिकाविहीनं स्थितिदलमर्केन्दुभुक्तिविवरेण ॥२०॥
संगुण्य खरस[६०]लब्धं तत्कृतिविक्षेपवर्गयुतम् ।
यत्तत्र भवति मूलं तेनोनं बिम्बमानयोगदलम् ॥२१॥
यच्छेषं तद्ग्रासं विक्षेपकलाविवर्जितं मध्ये ।

20(c-d)-22(a-b). Diminish (the *ghaṭīs* of) half the duration of the eclipse by the given *ghaṭīs*, then multiply by the motion-difference of the Sun and Moon, and then divide (the product) by 60. Add the square of that to the square of the Moon's latitude, and take the square root (of that sum). By that (square root) diminish half the sum of the diameters of the eclipsed and eclipsing bodies. The remainder is the measure of eclipse at the given time. (The minutes of half the sum of the diameters of the eclipsed and eclipsing bodies) diminished by the minutes of the Moon's latitude gives the measure of eclipse at the time of the middle of the eclipse.

GRAPHICAL REPRESENTATION OF *IṢṬA-GRĀSA*

तन्मूलसदृशसूत्रं मध्यात् प्राक्पश्चिमं नयेदिन्दोः ।
व्यस्तं रवेरिह, पथं स्पृशति यथास्थं तमो विलिखेत् ॥२२॥

22. Stretch a thread of length equal to the square root (obtained in the previous rule) from the centre towards the east or west of the Moon, or towards the west or east of the Sun (according as the given time relates to the first or second half of the eclipse), so as to

meet the path of the eclipsing body as it stands. At that point draw the Shadow.

APPROXIMATE METHOD FOR THE *IṢṬA-GRĀSA*

इष्टेन स्थित्यर्धे मध्यग्रासाङ्गुलानि सङ्गुण्य ।
हृत्वा स्थितिदलकालैरिष्टग्रासाङ्गुलं भवति ॥२३॥

23. Multiply the *aṅgulas* of the measure of eclipse at the time of the middle of the eclipse by the given time (elapsed since the first contact or to elapse before the the last contact) in *ghaṭīs* and divide (the product) by (the *ghaṭīs* of) half the duration of the eclipse: the quotient gives the measure of eclipse at the given time, in terms of *aṅgulas*.

SYNOPSIS

शशिरविफणिबिम्बोत्पत्ति-विक्षेप-काल-
त्रितयवलनलेख्यच्छाद्यदृश्यप्रदेशम् ।
सुगणकजनतुष्ट्यै प्राह सञ्चिन्त्य देवः
स्थितिदलसमयेष्टग्रासराहुभ्रमांश्च ॥२४॥

24. (In this chapter) Deva, after (careful) deliberation, has dealt with the following topics for the facility of good calculators: rules for finding the diameters of the Sun, Moon and Shadow, the Moon's latitude, laying off of the *valanas* for the three positions, the points where the eclipse is observed to begin and end, the time of half the duration of the eclipse, *iṣṭa-grāsa*, and the path of the Shadow.

इति करणरत्ने सोमग्रहणाधिकारो द्वितीयोऽध्यायः ।

Thus ends Chapter Two of the *Karaṇa-ratna*, dealing with Lunar Eclipse

CHAPTER 3

THE SOLAR ECLIPSE

THE ITERATED *LAMBANA*

पर्वाहृद्दलविवरजनाड्यस्त्वविशेषलम्बनपदानि ।
त्रिंशच्छिष्टानि तदा पञ्चदशभ्योऽधिकास्तु यदा ॥१॥

1. **The *nāḍīs* lying between midday and the end of the new moon *tithi* (*parva*) are the *padas* of the iterated *lambana*. When they exceed 15, they are subtracted from 30.[1]**

मनु[१४]रष्टाश्वि[२८]खवेदाः[४०]
खशर[५०]नवपञ्च[५९]रसषड्[६६]कमुनिः[७१] ।
शरगिरि[७५]वसुमुनि[७८]नवमुन्य[७९]-
शीतिरथ पञ्चसु[८०, ८०, ८०, ८०, ८०]त्रिगुणाः[×३] ॥२॥

2. **(The *vināḍīs* of the iterated *lambana* for 1, 2, ..., 15 *padas* are): 14, 28, 40, 50, 59, 66, 71, 75, 78, 79, 80, 80, 80, 80 and 80—each multiplied by 3.**

Below we state these *vināḍīs* of the iterated *lambana* in the tabular form. The corresponding values given in the *Vākya-karaṇa* (c. A. D. 1300) and in the *Makaranda-sāraṇī* (A. D. 1478) are also given to facilitate comparison.

1. *Cf.* Parameśvara's *Grahaṇa-maṇḍana*, vs. 42.

Table 8. Iterated *lambana* in terms of *vināḍīs*

nāḍīs of hour angle or *lambana-pada*	*lambana* in terms of *vināḍīs*		
	KR	*VāKa* (iv. 20A)	*MakSā* (Table 57)
1	42	37	42
2	84	78	84
3	120	115	116
4	150	144	151
5	177	172	176
6	198	192	193
7	213	208	214
8	225	219	226
9	234	227	234
10	237	231	238
11	240	234	240
12	240	238	239
13	240	240	235
14	240	240	229
15	240	240	221

APPLICATION OF ITERATED *LAMBANA*

पूर्वकपाले हीनं युतमपरे लम्बनेन पर्व स्यात् ।
तद्विषयांशेन तथा चन्द्रस्तस्मात्तु विक्षेपः ॥३॥

3. **In the eastern hemisphere (i. e., in the forenoon), the *parva* (i. e., the time of geocentric conjunction of the Sun and Moon) should be diminished by the (*vināḍīs* of the iterated) *lambana* and in the**

western hemisphere (i.e., in the afternoon), the *parva* should be increased by the (*vināḍīs* of the iterated) *lambana*. (Thus is obtained the time of apparent conjunction of the Sun and the Moon.)

The longitude of the Moon (for the time of conjunction) should be diminished or increased in the same way by 1/5 of that (*lambana* in *ghaṭīs*). From the resulting longitude (of the Moon) should be calculated the Moon's latitude.

The instruction that 1/5 of the *lambana-vināḍīs* are to be subtracted from or added to the Moon's longitude is based on the fact that the Moon's motion corresponding to the *lambana-vināḍīs*

$$= \frac{791 \times lambana\text{-}vin\bar{a}\d{d}\bar{\imath}s}{3600} \text{ mins.}$$

$$= \frac{lambana\text{-}vin\bar{a}\d{d}\bar{\imath}s}{5} \text{ mins.}$$

LOCAL LATITUDE

विषुवच्छायाव्यङ्गुलपिण्डं स्वत्र्यंशभागसंयुतया ।
सप्तत्या हृतलब्धं विषुवन्नाड्यः सदा याम्याः ॥४॥

4. **Divide the equinoctial midday shadow (of the gnomon), in terms of *vyaṅgulas*, by 70(1+1/3); the quotient gives the (local) latitude in terms of *nāḍīs*. It is always south.**[1]

That is:

$$\text{local latitude} = \frac{\text{equinoctial midday shadow in } vya\dot{n}gulas}{70(1+1/3)} \, n\bar{a}\d{d}\bar{\imath}s$$

$$= \frac{27(\text{equinoctial midday shadow in } a\dot{n}gulas)}{7} \text{ degrees.}$$

MERIDIAN-ECLIPTIC POINT (*MADHYA-LAGNA*)

दिनदलपर्वविशेषे षड्गुणितेंऽशा रवौ विशोध्यास्ते ।
पूर्वकपाले पश्चाद् देयाः तन्मध्यलग्नं स्यात् ॥५॥

1. *Cf. VSi*, III, i. 36; *Grahaṇa-maṇḍana*, vs. 45(b).

5. The time (in *ghaṭīs*) between midday and the *parva* (i.e., the time of conjunction of the Sun and Moon) should be converted into degrees by multiplying it by 6. These degrees should be subtracted from the longitude of the Sun for the time of conjunction (if the Sun is) in the eastern hemisphere and added to that (if the Sun is) in the western hemisphere. The result is (the longitude of) the meridian-ecliptic point.

ZENITH DISTANCE OF MERIDIAN-ECLIPTIC POINT

मध्यविलग्ना जीवा स्वशरांशोना विनाडिकापूर्वैः ।
समदिशि युता विशोध्या भिन्नायामधिकदिग्ग्राह्या ॥६॥

6. Diminish the Rsine of the longitude of the meridian-ecliptic point by one-fifth of itself : (the result is the declination of the meridian-ecliptic point, in terms of *vināḍīs*.) Take the sum or difference of this (declination) and the (local latitude in) *vināḍīs* (already obtained in vs. 4), according as they are of like or unlike directions: (the result is the zenith distance of the meridian-ecliptic point in terms of *vināḍīs*). Its direction is that of the greater of the two.[1]

Let λ, δ denote the longitude and declination of the meridian-ecliptic point. Then

$$\delta = \frac{300 \sin \lambda \times 1397}{300} \text{ mins. approx.}$$

$$= \frac{300 \sin \lambda \times 1397}{300} \times \frac{3600}{21600} \textit{ vināḍīs}$$

$$= \frac{300 \sin \lambda \times 4}{5} \textit{ vināḍīs approx.}$$

AVANATI (PARALLAX IN LATITUDE)

दशभक्ता तज्जीवा रविशशिनोर्भुक्तिविवरसंगुणिता ।
हृत्वा विद्येषुकृतै[४५१८]र्लब्धाऽवनतिः सुसूक्ष्मतरा ॥७॥

1. *Cf. Grahaṇamaṇḍana*, vs. 49.

7. **Divide that by 10 and then find the Rsine of that. Multiply that (Rsine) by the motion-difference of the Sun and Moon and divide by 4518: the quotient is the more accurate value of the *avanati*.**[1]

The following is the rationale of this rule :

$$avanati = \frac{d\d{r}kk\d{s}epajy\bar{a} \times (\text{motion-diff. of Sun and Moon})}{7905R/525} \text{ mins.,}$$

(*Vide* my notes on *LBh*, v. 11)

$$= \frac{d\d{r}kk\d{s}epajy\bar{a} \times (\text{motion-diff. of Sun and Moon})}{7905 \times 300/525} \text{ mins.,}$$

because here $R = 300'$

$$= \frac{\text{Rsin (z.d. of } madhya\text{-}lagna) \times (\text{motion-diff. of Sun and Moon})}{4518}$$

mins. approx.

MOON'S TRUE LATITUDE

विक्षेपस्यावनतेः प्रयुतिर्वियुतिः समान्यदिशोः ।
एवं स्फुटविक्षेपो दृक्क्षेपज्यां विनाऽपि धिया ॥८॥

8. **Take the sum or difference of the Moon's latitude and *avanati*, according as they are of like or unlike directions. This is how the Moon's true latitude is obtained without using the *dṛkkṣepajyā*, by the application of intellect.**

That is,

Moon's true latitude = Moon's latitude $\pm$ *avanati*,

$+$ or $\sim$ sign being taken according as Moon's latitude and *avanati* are of like or unlike directions.

IMPOSSIBILITY OF SOLAR ECLIPSE

सम्पर्कार्धकलायास्तुल्यायां वाऽथवाऽधिकायां वा ।
स्फुटविक्षेपावनतौ शशिमण्डलं रवेर्न रुणद्धि ॥९॥

1. *Cf. KK*, I, v. 3 ; *ŚiDVṛ*, I, xiii. 12(c-d).

9. When the Moon's true latitude equals or exceeds half the sum of (the diameters of) the eclipsed and eclipsing bodies, the Moon's disc does not cover the Sun's disc.[1]

MOON'S LATITUDE FOR FIRST AND LAST CONTACTS

स्थित्यर्धस्य शरांशं स्पर्शे लम्बनविशुद्धचन्द्रमसि ।
हित्वा दत्वा मोक्षे शशिविक्षेपस्ततः कार्यः ॥१०॥

10. (To obtain the Moon's latitude for the first or last contact:) first subtract one-fifth of the semi-duration of the eclipse (in terms of *vināḍīs*) from the Moon's longitude (for the time of conjunction) corrected for *lambana*, in the former case, and add the same in the latter case, and then find the Moon's latitude (*vide supra*, ch. ii, vs. 3).

It may be mentioned that :

Moon's motion corresponding to the *vināḍīs* of the semi-duration

$$\text{of the eclipse} = \frac{791 \times \textit{vināḍīs} \text{ of semi-duration}}{3600} \text{ minutes}$$

$$= \frac{\textit{vināḍīs} \text{ of semi-duration}}{5} \text{ minutes.}$$

THE THREE *VALANAS*

समदिशि वलनत्रितयं संयोज्यं भिन्नदिशि तु विश्लेष्यम् ।
ग्राहक इन्दुग्रहणे राहुः सूर्यग्रहे चन्द्रः ॥११॥

11. One should take the sum or difference of the three *valanas* (taking two at a time) according as they are of like or unlike directions.

***Rāhu* (i.e., Shadow) is the eclipser in the lunar eclipse and Moon in the solar eclipse.**

प्रग्रहणमोक्षकालिकविक्षेपादानयेद्वलनान् ।

12(a-b). Calculate the *valanas* (for the first and last contacts) with the help of the Moon's latitude for those times, as follows:

1. *Cf. LBh*, v. 15.

1. *VIKṢEPA-VALANA*

युतबिम्बार्ध-प्रग्रहमोक्षस्थित्यर्धलिप्तिकाविवरम् ॥१२॥

वर्गीकृतं च साग्रं निजविक्षेपस्य कृतिसहितम् ।

मूलं ग्राह्यतनुघ्नं ग्राह्यग्राहकसमेतबिम्बहृतम् ॥१३॥

विक्षेपवलनमेतद्विक्षेपसमा दिगस्य स्यात् ।

12(c-d)-14(a-b). Find the difference of (i) half the sum of the eclipsed and eclipsing bodies and (ii) half the duration of eclipse towards the first or last contact, in terms of minutes. Square it and then increase it by the square of the Moon's own latitude (for that time). Multiply the square root of that (sum) by the diameter of the eclipsed body and divide by the sum of the diameters of the eclipsed and eclipsing bodies. This is the *vikṣepa-valana* and its direction is the same as that of the Moon's latitude.

2. *AYANA-VALANA*

त्रिभवनरहिताच्चन्द्रात् प्रग्रहणे तैः समन्वितान्मोक्षे ॥१४॥

बाहुज्यां कृतवेदैर्हृत्वाऽऽगतमयनवलनं स्यात् ।

14(c-d)-15(a-b). In the case of the first contact, subtract three signs from the Moon's longitude, and in the case of the last contact, add three signs to the Moon's longitude. Find the Rsine of the *bāhu* thereof and divide that by 44. What is thus obtained is the *ayana-valana*.

3. *AKṢA-VALANA*

कालविनाड्यो द्युदलत्रिभागभक्तास्तु राशयो ज्ञेयाः ॥१५॥

राशित्रितयं हित्वा स्पर्शे मोक्षे च दत्त्वा दिक् ।

तद्बाहुज्यां विषुवच्छायोत्थविनाडिकागुणां कृत्वा ॥१६॥

रसकृतमुनिगगनेन्दु[१०७४६]भिराप्तं स्यादक्षवलनं तत् ।

15(c-d)-17(a-b). Divide the *vināḍīs* of the hour angle by (the *vināḍīs* of) one-third of half the duration of the day: the result is (the hour angle) in terms of signs. In the case of the first contact, subtract 3 signs from that and in the case of the last contact, add three signs to that. Multiply the Rsine of the *bāhu* of that by the *vināḍīs* (of the local latitude) arising from the equinoctial midday shadow and divide by 10746: the result is the *akṣa-valana*.

That is, if D, D' denote the diameters of the Sun and Moon ; M, β and H, the longitude, latitude and hour angle of the Moon at the time of the first or last contact ; and d the semi-duration of the eclipse in minutes, then

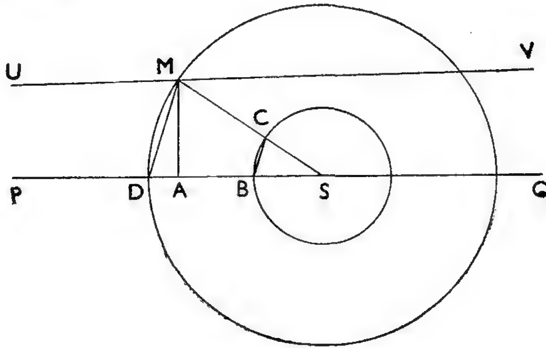
$$\textit{vikṣepa-valana} = \frac{\sqrt{\{\frac{1}{2}(D+D')-d\}^2+\beta^2} \times D}{D+D'} \text{ mins.}$$

$$\textit{ayana-valana} = \frac{300 \sin (M \pm 90^\circ)}{44} \text{ mins.}$$

$$\textit{akṣa-valana} = \frac{300 \sin (H \pm 90^\circ) \times (\text{local latitude in } \textit{vināḍīs})}{10746} \text{ mins.}$$

— or + sign being taken according as it is the time of the first contact or last contact.

Rationale. In the figure below, let S be the centre of the Sun, and let the smaller circle represent the Sun and the bigger one the *samparkārdha-vṛtta* (drawn with radius equal to half the sum of the diameters of the Sun and Moon). Let PQ be the ecliptic and UV the Moon's orbit. Let M be the Moon at the time of the first or last contact, MA the perpendicular drawn from M on the ecliptic, and C the point where MS intersects the Sun's circumference.



Now $DA=MS-AS=\frac{1}{2}(D+D')-d$.

$$\therefore\ MD=\sqrt{DA^2+MA^2}=\sqrt{\{\tfrac{1}{2}(D+D')-d\}^2+\beta^2}.$$

Now, comparing the triangles BCS and DMS, we get

$$\textit{vikṣepa-valana}\ BC=\frac{MD\times CS}{MS}$$

$$=\frac{\sqrt{\{\tfrac{1}{2}(D+D')-d\}^2+\beta^2}\times D}{D+D'}\text{ mins.}$$

Again,

$$\textit{ayana-valana}^1=\frac{300\sin(M\pm 90^\circ)\times 1397}{300}\text{ mins., for the circle of radius } 3438'$$

$$=\frac{300\sin(M\pm 90^\circ)\times 1397}{300}\times\frac{16{\cdot}5}{3438}\text{ mins., for the Sun's disc (radius 16·5 mins.)}$$

$$=\frac{300\sin(M\pm 90^\circ)}{44}\text{ mins., for the Sun's disc.}$$

Again,

Half the duration of the day = 15 *nāḍīs* or 900 *vināḍīs*

One-third of that = 5 *nāḍīs* or 300 *vināḍīs*.

Since 5 *nāḍīs* or 300 *vināḍīs* correspond to one sign, therefore hour

$$\text{angle in terms of signs}=\frac{\text{hour angle in } \textit{vināḍīs}}{\text{one-third of half the duration of day}}$$

$$\therefore\ \textit{akṣa-valana}^1=\frac{300\sin(H\pm 3\text{ signs})\times(\text{latitude in mins.})}{300}\cdot\frac{16}{3438}\text{ mins.}$$

for the Sun's disc (radius 16′)

1. This is the basic formula used by the author.

$$= \frac{300 \sin (H \pm 3 \text{ signs}) \times (\text{lat. in } vin\bar{a}\d{d}\bar{\imath}s) \times 6 \times 16}{300 \times 3438} \text{ mins.}$$

$$= \frac{300 \sin (H \pm 3 \text{ signs}) \times (\text{latitude in } vin\bar{a}\d{d}\bar{\imath}s)}{10746} \text{ mins. approx.}$$

TRUE SEMI-DURATIONS IN A SOLAR ECLIPSE

लम्बनान्तरसंयुक्ते स्थित्यर्धे विनिर्दिशेत् स्फुटे ।।१७।।[1]

17(c-d). Half the semi-duration of the eclipse (towards the first contact) should be increased by the difference between the *lambanas* for the first contact and the middle of the eclipse; and half the semi-duration of the eclipse (towards the last contact) should be increased by the difference between the *lambanas* for the middle of the eclipse and the last contact. The results thus obtained should be declared as the true values of the two semi-durations of the eclipse.

MEASURE OF ECLIPSE (*GRĀSA*)

युतबिम्बार्ध-विक्षेपविश्लेषो ग्रास उच्यते ।

पक्षाग्नि[३२]गुणितो ग्राह्यबिम्बभक्तः स्फुटः स्मृतः ।।१८।।

18. The difference of (i) half the sum of the diameters of the eclipsed and eclipsing bodies and (ii) the Moon's latitude (both for the time of conjunction and in terms of minutes of arc) is called the measure of eclipse. That multiplied by 32 and divided by the diameter of the eclipsed body is called the true value thereof.[2]

THE EIGHT PHASES OF A SOLAR ECLIPSE

ग्रासैः सप्तभिरष्टमं द्विकुलवैर्भागं चतुर्थं वदेद्

वेदैकैस्तु तृतीयमङ्गशशिभिश्चार्धं गृहीतं रवेः ।

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1. Vs. 17(c-d) is exactly the same as *LBh*, v. 14(c-d).
2. Paramesvara gives a similar rule for *sphuṭa-valana*. See *Grahaṇa-maṇḍana*, vss. 78(c-d)—79.

सर्वं लोकयमैस्त्रिभागरहितं पादोनमङ्गाश्विभि-
र्हीनं स्वाष्टमभागतो नवयमैरिन्दोः तथैकान्वितम् ॥१९॥

19. When the eclipsed portion (of the Sun's diameter) amounts to 7′, 1/8 (of the Sun's diameter) should be declared as eclipsed; when 12′, 1/4; when 14′, 1/3; when 16′, 1/2; when 23′, 1—1/3 (=2/3); when 26′, 1—1/4 (=3/4); when 29′, 1—1/8 (=7/8); when 32′, 1.

A similar statement is found to occur in the *Karaṇa-kaustubha*[1] of Kṛṣṇa-daivajña (A.D. 1653), son of Mahādeva, resident of Taṭāka-nagara in Konkan (Mahārāṣṭra).

SYNOPSIS

अविशेषितलम्बनं च लग्नं स्फुटविक्षेपमवानतेर्विशुद्धम् ।
ग्रहणस्य च मानमष्टभेदप्रभवं सविधानमाह देवः ॥२०॥

20. In this chapter, Deva has dealt with the following topics along with the (relevant) rules : iterated *lambana*, (*madhya*) *lagna*, Moon's true latitude, the *avanati* correction, and the eight phases of the eclipse.

इति करणरत्ने सूर्यग्रहणाधिकारस्तृतीयोऽध्यायः ।

Thus ends Chapter Three of the *Karaṇa-ratna*, dealing with the Solar Eclipse.

1. vii. 6(c-d)—7(i), 11.

CHAPTER 4

PROBLEMS BASED ON THE GNOMONIC SHADOW

1. MERIDIAN SHADOW FROM PLANET'S LONGITUDE

DECLINATIONS IN *VINĀḌĪS*

चत्वारिंशद[४०]शीतिः[८०]
स्वररुद्राः[११७]शशिशरेन्दु[१५१]शशिविद्याः[१८१] ।
ऋतुखयमाः[२०६] तत्त्वयमा[२२५]
रसगुणयुगलं[२३६]खवेदाक्षि[२४०] ॥१॥

एतानि रविशशिभुजादशभागपदानि

1-2(a-b). 40, 80, 117, 151, 181, 206, 225, 236 and 240—these are the *padas* (or the declinations in terms of *vināḍīs*) corresponding to every 10° of the *bhujā* (i.e., longitude, reduced to *bhuja*) of the Sun or Moon.[1]

The following table explains it clearly :

Table 9. The declination table.

bhuja of Sun or Moon	declination in minutes (i.37)	declination in *vināḍīs*
10°	242	40
20°	479	80
30°	703	117

1. The literal translation is :
"*Catvāriṁśat* (= 40), *aśītiḥ* (= 80),........., *khavedākṣi* (= 240) — these are the word-chronograms (giving the declinations in terms of *vināḍīs*) corresponding to every 10° of the *bhujā* of the Sun or Moon."

40°	908	151
50°	1088	181
60°	1237	206
70°	1347	225
80°	1416	236
90°	1440	240

ZENITH-DISTANCES IN *VINĀḌ S*

विषुवदुत्पन्ने ।

सहितरहितानि कृत्वा समभिन्नदिशोस्तु,

2(b-d). **These (declinations) should be added to or subtracted from the local latitude (in terms of *vināḍīs*), according as the two are of like or unlike directions. (Then are obtained the meridian zenith distances, in terms of *vināḍīs*, of the same points of the ecliptic.)**

The direction of the local latitude is always south. (See *supra* iii,4)

24 SUBTRACTIVE *PADAS* OR MERIDIAN Z. D.—DIFFERENCES CORRESPONDING TO SHADOW-*AṄGULAS*

शोध्यानि ॥२॥

वसुकृत[४८]मुनिवेदं[४७] षट्कृतं[४६] वेदवेदं[४४]

यमकृत[४२]नवलोकं[३९] शैललोकं[३७] शराग्निम्[३५] ।

गुणशिखि[३३]नवनेत्रा[२९]ण्यद्रिपक्षाः[२७]शराश्वि[२५]-

यमकर[२२]शशियुग्मे[२१]विंशतिः[२०]शैलरूपम्[१७] ॥३॥

रसेन्दवो[१६]मनु[१४]स्तथा गुणेन्दु[१३]रर्क[१२]शङ्कराः [११] ।

दिशो[१०]नवाष्टकं[९, ८]पदं चतुर्युताऽत्र विंशतिः ॥४॥

2(d)-4. **Subtractive *Padas* : 48, 47, 46, 44, 42, 39, 37, 35, 33, 29, 27, 25, 22, 21, 20, 17, 16, 14, 13, 12, 11, 10, 9 and 8, these being 24 *padas* in all.**

The following table explains it clearly :

Table 10. Midday shadow and Sun's meridian zenith distance.

aṅgulas of midday shadow	Sun's meridian z. d. in *vināḍīs*	differences or (subtractive) *padas* in *vināḍīs*
1	48	48
2	95	47
3	141	46
4	185	44
5	227	42
6	266	39
7	303	37
8	338	35
9	371	33
10	400	29
11	427	27
12	452	25
13	474	22
14	495	21
15	515	20
16	532	17
17	548	16
18	562	14
19	575	13
20	587	12
21	598	11
22	608	10
23	617	9
24	625	8

MERIDIAN SHADOW

यावन्ति शुद्धानि पदानि तस्मात्
तावत्य एवाङ्गुलयो दिनार्धे ।
छायैवमिन्दोरपि बाहुजीवा
विक्षेपषड्भागयुतोनिता च ॥५॥

5. **As many (subtractive) *padas* can be subtracted (from the *vināḍīs* of the Sun's meridian zenith distance), so many *aṅgulas* there are in the midday (shadow of the gnomon). The meridian shadow of the gnomon due to the Moon may also be obtained in this way, but in the Moon's case the *vināḍīs* of the Moon's zenith distance should also be increased or diminished by one-sixth of the minutes of the Moon's latitude (i.e. by the *vināḍīs* of the Moon's latitude) (as the case may be).**

2. TIME FROM *LAGNA*

RIGHT AND OBLIQUE ASCENSIONS OF SIGNS

वसुभं [२७८] व्येकत्रिशतं [२९९] शिखियमदहनं [३२३]-
क्रमोत्क्रमान्न्यस्य ।
चरदलविरहितसहितं मेषादि तुलादि चोत्क्रमतः ॥६॥

6. **First write down the numbers 278, 299, and 323 in the serial order and then the same numbers in the reverse order : (the six numbers thus written down denote the right ascensions, in terms of *vināḍīs*, of the six signs beginning wtth Aries. The same numbers in the reverse order are the right ascensions, in terms of *vināḍīs*, of the six signs beginning with Libra). Now diminish the numbers 278, 299 and 323 by the ascensional differences, in terms of *vināḍīs*, of the signs Aries, Taurus and Gemini respectively and write them down in the serial order ; then increase the same numbers by the ascensional differences, in terms of *vināḍīs*, of the signs Aries, Taurus and Gemini, and write them down in the reverse order. The six numbers thus written down are the oblique ascensions, in terms of *vināḍīs*, of the six signs beginning with Aries ; and the same six numbers in the reverse order are the oblique ascensions, in terms of *vināḍīs*, of the six signs beginning with Libra.[1]**

1. *Cf.* *K̆K*, I, iii. 4.

The right ascensions (or the times of rising at the equator) of the signs may be stated in tabular form as follows :

Table 11. Right ascensions of the signs.

Sign	Right ascension in *vināḍīs*	Sign
1. Aries	278	12. Pisces
2. Taurus	299	11. Aquarius
3. Gemini	323	10. Capricorn
4. Cancer	323	9. Sagittarius
5. Leo	299	8. Scorpio
6. Virgo	278	7. Libra

Assuming a, b, c, to be the ascensional differences, at the local place, of the signs Aries, Taurus and Gemini respectively, in terms of *vināḍīs*, the oblique ascensions (or the times of rising at the local place) of the signs may be stated in tabular form as follows :

Table 12. Oblique ascensions of the signs.

Sign	Oblique ascension in *vināḍīs*	Sign
1. Aries	278—a	12. Pisces
2. Taurus	299—b	11. Aquarius
3. Gemini	323—c	10. Capricorn
4. Cancer	323+c	9. Sagittarius
5. Leo	299+b	8. Scorpio
6. Virgo	278+a	7. Libra

TIME FROM *LAGNA*

अर्केन्द्रभुक्तलिप्ताः स्वोदयगुणिता नभोऽम्बरपुराणैः [१८००] ।
लब्धाः पुरोदययुताः प्रागलग्नाल्लग्नकालः स्यात् ॥७॥

7. Multiply the minutes to be traversed of the sign occupied by the Sun or Moon by the oblique ascension of that sign and divide by 1800. Add the resulting (*asus*) to the (*asus* of the) oblique ascensions of the (succeeding) signs which have risen prior to the rising point of the ecliptic (*lagna*). This is how time is obtained from (the longitude of) the *lagna*.

There are 21600 *asus*, 3600 *vināḍīs* and 60 *nāḍīs* in a sidereal day, so that the *asus* divided by 6 give the *vināḍīs* and the *vināḍīs* divided by 60 give the *nāḍīs*.

3. SHADOW FROM TIME

षड्गुणितेष्टविनाड्यः तदहर्विघटी[१८००]हृतास्तु भवनानि ।
दोर्ज्या शङ्कुदिनार्धच्छायाकृतियोगमूलमपि ॥८॥
त्रिशतगुणे ज्याभजिते लब्धकृतौ शङ्कुवर्गरहितायाम् ।
मूलं षष्ट्या लब्धं छाया पूर्वापरकपाले ॥९॥

8-9. Multiply the given *vināḍīs* (elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon) by 6 and divide by the *vināḍīs* in a day (i. e., by 1800) : the result is the signs corresponding to time elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon (i. e., *unnata-kāla*). Find the Rsine of these signs (and set it down at some place to be used later). Now find the square root of the sum of the squares of the gnomon and (the *vyaṅgulas* of) the midday shadow. Multiply this (square root) by 300 and divide by the Rsine (kept at the other place), and diminish the square of the result by the square of the gnomon. The square root thereof divided by 60 gives the shadow (in terms of *aṅgulas*) in the eastern or western hemisphere (as the case may be).[1]

That is :

$$\text{Desired shadow in } a\dot{n}gulas = \frac{\sqrt{\left(\dfrac{\text{root} \times 300}{\text{Rsine}}\right)^2 - (\text{gnomon})^2}}{60}$$

1. This rule is based on the rule given in *BrSpSi*. xxv. 68.

where root $= \sqrt{(\text{midday shadow in } vya\dot{n}gulas)^2 + (\text{gnomon})^2}$

and Rsine $= \text{Rsin}\left[\dfrac{\text{given } vin\bar{a}\d{d}\bar{\imath}s \times 6}{vin\bar{a}\d{d}\bar{\imath}s \text{ in a day}} \text{signs}\right]$,

gnomon being in *vyaṅgulas.*

Rationale. Here the so called "Rsine" is what is usually known as "*iṣṭa antyā*" and the "root" is the hypotenuse of the midday shadow.

The rule is based on the following inverse proportion : "When the hypotenuse of the midday shadow corresponds to the *antyā* for midday (which is roughly equal to the radius 300′) what shall correspond to the *iṣṭa antyā* (i. e., *antyā* for the desired time)?" The result is :

$$\text{Hypotenuse of desired shadow} = \frac{\text{hypotenuse of midday shadow} \times 300}{i\d{s}\d{t}a\ anty\bar{a}}\ vya\dot{n}gulas.$$

$$= \frac{\text{root} \times 300}{\text{Rsine}}\ vya\dot{n}gulas$$

SHADOW OF MAN

सप्तगुणेष्टच्छाया रविसंख्याभाजिता पदच्छाया ।

भूयस्सा रविगुणिता स्वेष्टच्छायैव सप्ताप्ता ॥१०॥

10. **The given shadow (of the gnomon of 12 *aṅgulas*) (in terms of *aṅgulas*) multiplied by 7 and divided by 12, gives the shadow of man in terms of human feet. Conversely, the shadow of a man (in terms of human feet) multiplied by 12 and divided by 7, gives the desired shadow (of the gnomon in terms of *aṅgulas*).**

This rule is based on the usual assumption that the height of a man is equal to 7 human feet.

4. TIME FROM SHADOW

मध्यच्छायाशङ्कोः कृतियुतिमूलं त्रिभिः शतैर्गुणितम् ।

शङ्क्विष्टच्छायाकृतिसमासमूलोद्धृतं ज्या स्यात् ॥११॥

जीवापिण्डाज्जीवां हृत्वा हृत्वा क्षिपेद् दश-दशांशान् ।
दशगुणशेषं हृत्वा स्थितिज्यया योज्य इति काष्ठा ॥१२॥

सा रविशशिनोर्दिनदलगुणिता वियत्खजलधिविषय-
[५४००]विहृता ।
षष्टिहृता गतनाड्यो दिवसविशुद्धाः स्युरपराह्णे ॥१३॥

11. Find the square root of the sum of the squares of the midday shadow and the gnomon. Multiply that (square root) by 300 and divide by the square root of the sum of the squares of the gnomon and the given shadow : the result is the so called "Rsine".

12. From this Rsine subtract as many tabular Rsine-differences as possible and for each Rsine-difference subtracted take 10° and sum them up. The ultimate residue should be multiplied by 10 and divided by the current Rsine-difference : the resulting degrees should also be added to the previous sum. The sum (thus obtained) gives (the degrees in) the arc (corresponding to the "Rsine").

13. That arc multiplied by (the *vināḍīs* in) half a day of the Sun or Moon (as the case may be) and divided by 5400 and also by 60 gives the *nāḍīs* elapsed (in the forenoon) or the same *nāḍīs* subtracted from the *nāḍīs* in a day give the *nāḍīs* to elapse in the afternoon.[1]

That is :

Desired time in *nāḍīs*

$$= \frac{\text{arc}\left[\frac{\sqrt{(\text{midday shadow})^2+(\text{gnomon})^2}\times 300}{\sqrt{\{(\text{given shadow})^2+(\text{gnomon})^2\}}}\right]\times \text{(semi-duration of day in } vin\bar{a}\d{d}\bar{\imath}s)}{5400\times 60}.$$

This rule is just the converse of the rule stated in vss. 8-9, and can be easily deduced therefrom.

1. This rule is based on the rule given in *BrSpSi*, xxv. 69.

5. *LAGNA* FROM TIME

लग्नार्थं रविशशिनोरभुक्तलिप्ता निजोदयाभ्यस्ताः ।
राशिकलाभिर्लब्धान् स्वेष्टविनाडीगणात्त्यक्त्वा ॥१४॥
सम्पूर्य वर्तमानं राशिमुपर्युद्गमान् त्यजेच्छेषात् ।
राशिस्तस्मिन्नेव क्षिपेत् तदा भवति लग्नं तत् ॥१५॥

14-15. To find the longitude of the rising point of the ecliptic (proceed as follows) : Multiply the untraversed portion of the sign occupied by the Sun or Moon by that sign's own time of rising (at the local place) and divide by the number of minutes in a sign (i. e., by 1800) ; then subtract the resulting (*vināḍīs*) from the given time, in terms of *vināḍīs*; then having completed the current sign, subtract from the residue (of the *vināḍīs*) the times of rising of as many succeeding signs (or part of a sign) as possible, and add those signs (and part of a sign, if any) (to the completed sign) Whatever is thus obtained is the longitude of the rising point of the ecliptic (called *lagna*).

SYNOPSIS

ग्रहतो मध्यच्छाया तत्कालोऽस्याः ततः स्फुटच्छाया ।
तस्याः कालस्तस्माद्विलग्नमिति पञ्चविधमेतत् ॥१६॥
तत्पञ्चदशार्याभिर्देवो गोजन्मसूनुरत्राह ।
स्वाहोरात्रस्थितिचरलम्बाक्षज्यां विनाऽपि स्वधिया ॥१७॥

16-17. Midday shadow from the planet's longitude, time from that (midday shadow),[1] gnomonic shadow from that (time), time from that (shadow), *lagna* from that (time) — these five determinations have been stated here (in this chapter) in 15 *āryā* verses by Deva, son of Gojanma, by using his own intellect, without utilizing the (planet's) position on the diurnal circle, the ascensional difference, latitude or colatitude.

इति करणरत्ने चतुर्थोऽध्यायः

Thus ends Chapter Four of the *Karaṇa-ratna.*

1. More correctly, time from *lagna*.

CHAPTER 5

MOONRISE AND RELATED PROBLEMS

MOON'S LONGITUDE AND LATITUDE AT SUNSET

आनीय रविशशाङ्कौ स्फुटभुक्तिदलेन विरहितं कृत्वा ।
अस्तमये तौ भवतौ विक्षेपं चानयेदिन्दोः ॥१॥

1. Having obtained the longitudes of the Sun and the Moon (for sunrise on the full moon day), diminish them by half the true daily motions (of the Sun and Moon, respectively). Then are obtained the longitudes (of the Sun and the Moon) for sunset. Also calculate (therefrom) the latitude of the Moon (for sunset).

THE VISIBILITY CORRECTIONS

(i) *AKṢA–DṚKKARMA*

विषुवच्छायागुणितो विक्षेपो रविहृतः शशिन्युदये ।
उत्तरतो विश्लेषो याम्ये योज्योऽस्तगे व्यस्तम् ॥२॥

2. Multiply the Moon's latitude by the equinoctial midday shadow and divide (the product obtained) by 12: (the result is the *akṣa-dṛkkarma* for the Moon). In the case of moonrise, subtract it from or add it to the Moon's longitude according as the Moon's latitude is north or south. In the case of moonset, the law of addition and subtraction is just the reverse.[1]

That is :

$$\text{Moon's } dṛkkarma = \frac{\text{Moon's latitude} \times \text{equinoctial midday shadow}}{12}$$

1. *Cf. PSi*, v. 8 ; *KK*, I,vi. 3.

For the rationale of this formula, see my notes on *MBh*, vi. 1-2(i) or *Ā*, iv. 35.

(ii) *AYANA-DṚKKARMA*

विक्षेपो राशित्रययुतशशिजीवाहतोऽद्रिगुणशैलैः [७३७] ।
लब्धो विक्षेपायनसमदिशि शोध्योऽन्यत्र विक्षेपः ॥३॥

3. **Multiply the Moon's latitude by the Rsine of the Moon's longitude as increased by 3 signs and divide by 737 : the result (which is known as the *ayana-dṛkkarma*) should be subtracted from the longitude of the Moon, if the Moon's latitude and *ayana* are of like directions. In the contrary case, it should be added.**

That is,

$$\text{Moon's } \textit{ayana-dṛkkarma} = \frac{\text{Rsin }(M+3 \text{ signs})\times(\text{Moon's latitude})}{737}$$

where $R = 300'$ and M is the Moon's tropical longitude.

This formula is equivalent to that given by Brahmagupta in his *Khaṇḍakhādyaka*.[1] For its rationale, see my notes on *MBh*, vi. 2(ii)-3 or *Ā*, iv. 36.

For the meaning of the word *ayana*, see infra, Appendix 1, stanzas 20 and 31.[2]

THIRD VISIBILITY CORRECTION

मङ्गलवेदा[४८]श्च कलाः प्राक्पश्चाद्भागयोः ऋणधनं स्यात् ।
एभिस्त्रिभिर्विधानैः दर्शनयोग्यो भवति चन्द्रः ॥४॥

1. See *KK*, I, vi. 2.

2. It must be noted here that, according to the commentators of the *Khaṇḍakhādyaka*, whenever one is required to find the Rsine of the longitude after adding three signs to it as in the above rule, one should find the Rversed sine of the *bhuja* thereof. So Rsin (M+3 signs) means, according to them, Rvers (*bhuja* of M+3 signs). See the commentaries of Pṛthūdaka, Bhaṭṭotpala and Āmarāja on *KK*, I, vi. 2.

Similarly, the *ayana* in the above rule means, according to Pṛthūdaka and Bhaṭṭotpala, the *ayana* of the Moon as increased by 3 signs, and not the *ayana* of the Moon. Āmarāja, however, takes it to mean the *ayana* of the Moon itself.

4. 48 minutes too should be subtracted from the Moon's longitude or added to that according as the Moon is in the eastern or western hemisphere. By applying these three corrections, the Moon becomes fit for observation (at sunset).

This correction is probably meant to account for the difference between the horizontal parallaxes of the Moon and the Sun. 48′ is evidently the difference between the horizontal parallaxes of the Moon and the Sun. For, according to Āryabhaṭa I :

Moon's horizontal parallax = 52′ 30″

Sun's horizontal parallax = 3′ 56″.

MOONRISE RELATIVE TO SUNSET

सूर्यश्चक्रार्धयुतः तदा विलग्नं यदीन्दुरूनोऽस्मात् ।
पूर्वमुदेत्यधिकश्चेत् पश्चात् दिवसाधिपास्तमयात् ।।५।।

5. Increase the longitude of the Sun for sunset by 6 signs : the result is the longitude of the horizon-ecliptic point in the east. If the longitude of the Moon (for sunset) is less than that, the Moon rises before sunset ; if greater, after sunset.

TIME OF MOONRISE

राश्युदयैरानीयात् तत्कालं चन्द्रलग्नतः प्राग्वत् ।
रात्रौ तु नाडिकाः स्युः क्षेप्यास्त्याज्या दिवाऽभ्युदितैः ।।६।।

6. The time of moonrise should be obtained from the Moon's longitude, the longitude of the rising point of the ecliptic, and the oblique ascensions of the signs, as before. When moonrise occurs in the night (i. e., after sunset) the *nāḍīs* (intervening between the Moon and the rising point of the ecliptic) should be added to the measure of the day ; when moonrise occurs in the day (i. e., before sunset) the *nāḍīs* (intervening between the Moon and the setting point of the ecliptic) should be subtracted from the measure of the day :(the result in either case is the time of moonrise reckoned since sunrise).

MOON'S SHADOW ETC.

ताभिः शशिनश्च्छाया 'षड्गुणिते'तिक्रमेण बोद्धव्याः ।
पञ्चप्रश्नविधानं सूर्यवदत्रापि सञ्चिन्त्यम् ॥७॥

7. From those *nāḍīs* (intervening between the Moon and the rising or setting point of the ecliptic), one may obtain the gnonomic shadow due to moonlight by applying the rule : "Multiply the given *vināḍīs* by 6, etc." (*vide supra*, ch. iv. vss. 8-9). Methods for solving the five problems (*vide supra*, ch. iv. of vss. 16-17) should also be contemplated here (in the case of the Moon) too as in the case of the Sun.

इति करणरत्ने पञ्चमोऽध्यायः

Thus ends Chapter Five of the *Karaṇa-ratna.*

CHAPTER 6

ELEVATION OF MOON'S HORNS

INVOCATION AND INTRODUCTION

यस्यांशुभक्षणाद्युरमृतत्वं सुरगणा यमीशोऽपि ।
शिरसा बिभर्ति शृङ्गोद्गमनं वक्ष्यामि तस्येन्दोः ॥१॥

1. I shall now deal with the elevation of the horns of that Moon whom God *Śiva* bears on His head and feeding on whose rays the gods have achieved immortality.

HELIACAL VISIBILITY OF THE MOON

कृत्वाऽत्र पौर्णमासीविधानकथितं स्फुटत्रयं शशिनि ।
अस्य दिवसप्रमाणं बिम्बं च प्राग्वदानीयात् ॥२॥

रविचन्द्रान्तरकाले राशीनामुदयास्तमयपिण्डम् ।
प्रागपरयोर्यदि स्याद् दृश्यो नाडीद्वयं चन्द्रः ॥३॥

2. Having applied the three (visibility) corrections, stated in connection with the instructions pertaining to the full moon day, to the Moon's longitude (for sunrise or sunset), find the measure of its (i e., Moon's) day as also the diameter of its disc in the manner described heretofore.

3. If the sum of the times of rising or setting (at the local place) of the signs intervening between the Sun and the Moon (as corrected

for the visibility corrections) amounts to two *nāḍīs*, the Moon shall be visible towards the east (before sunrise) or towards the west (after sunset).

MOON'S ILLUMINATED PART AND *ŚAṄKVAGRA*

ता विघटिका नवत्या हृताः शशिदिनदलविघटिकालब्धाः ।
भागास्तेषां जीवा शङ्कुरयं चन्द्रबिम्बघ्नः ॥४॥

षड्भिः शतैर्विभक्तं सितमानं बिम्बशुद्धमसितं स्यात् ।
विषुवद्भवगुणशङ्कुस्त्रिशतविभक्तस्तु शङ्क्वग्रम् ॥५॥

4. **Multiply those *vighaṭikās* (i.e., the *vighaṭikās* intervening between the Sun and the Moon) by 90 and divide by the *vighaṭikās* of half the Moon's day. Thus are obtained the degrees (intervening between the Sun and the Moon). Their Rsine is to be designated as *Śaṅku*.**

5. **Multiply that (*Śaṅku*) by the diameter of the Moon and divide by 600 : the result is the illuminated part of the Moon. That subtracted from the diameter of the Moon is the unilluminated part.**

   The *Śaṅku* multipled by the Rsine of latitude and divided by 300 is the (Moon's) *Śaṅkvagra*.

That is :

$$\text{Moon's illuminated part} = \frac{\acute{S}a\dot{n}ku \times \text{Moon's diameter}}{600} \qquad (1)$$

$$\text{and Moon's } \acute{S}a\dot{n}kvagra = \frac{R \sin \phi \times \acute{S}a\dot{n}ku}{300}, \qquad (2)$$

where ϕ is the local latitude, and $R = 300'$.

One can easily see that the *Śaṅku* defined above is in fact the Moon's *iṣṭahṛti*.

Formula (1) follows from the following proportion : When the distance between the Sun and the Moon amounts to 90° and likewise the

Rsine of that distance is equal to 300′ the illuminated part of the Moon amounts to half the diameter of the Moon, what illuminated part of the Moon will correspond to the Rsine of the given distance between the Sun and the Moon ?

Formula (2) results from the comparison of the following latitude triangles :

	base	upright	hypotenuse
(1)	Moon's *śaṅkvagra*	Rsin (Moon's altitude)	Moon's *iṣṭahṛti* or *Śaṅku*
(2)	$300 \sin \phi$	$300 \cos \phi$	300′

AGRĀS OF SUN AND MOON AND *KOṬI* OF ELEVATION TRIANGLE

अर्केन्दुबाहुजीवा निजविषयांशोनिता तयोरग्रे ।
चन्द्राग्रे शङ्क्वग्रं युतवियुतं स्यात् समान्यदिशोः ॥६॥

षड्भागो विक्षेपस्यापि तदा तद् विशुद्धमिन्द्वग्रम् ।
तस्य च सूर्याग्रस्य च युतिवियुतिर्भिन्नसदृशदिशोः ॥७॥

6-7. Find the Rsines of the *bāhus* of the longitudes of the Sun and the Moon, and diminish them by one fifths of themselves : (the results are the declinations of the Sun and the Moon, in terms of *vināḍīs*).[1] From these (declinations) calculate the *agrās* of the Sun and the Moon. Take the sum or difference of the Moon's *agrā* and Moon's *śaṅkvagra*, according as they are of like or unlike directions : (the result is the so called Moon's *bhuja*). If one-sixth of the Moon's latitude (in terms of minutes of arc) is also applied to the Moon's declination (in terms of *vināḍīs*)[2], then the value of the Moon's *agrā* becomes accurate. Now take the sum or difference of that (Moon's *bhuja*) and the Sun's

1. See *supra*, iii. 6.
2. When the Moon's latitude, in terms of minutes, is divided by 6, it is reduced to *vināḍīs*.

***agrā*, according as they are of unlike or like directions : (the result is the *Koṭi* of the elevation triangle in terms of *vināḍīs*).**

The *agrā* is obtained by the formula :

$$agr\bar{a} = \frac{\text{R} \sin \delta \times 300}{300 \cos \phi}$$

where δ is the declination and ϕ the local latitude.

The sum or difference of the Moon's *agrā* and Moon's *śaṅkvagra* gives the distance of the foot of the perpendicular dropped from the Moon on the plane of the horizon from the east-west line. The Sun's *agrā* (at sunrise or sunset) is equal to the distance of the Sun from the east-west line.

The sum or difference of the Moon's *bhuja* and the Sun's *agrā* gives the north-south distance between the Sun and the Moon. This is generally known as *spaṣṭa-bāhu.* But in the present work it has been called *Koṭi.*

THE TRUE *KOṬI*

तद्‌बिम्बगुणं कृतहृतशङ्कुविभक्तं तु भवति कोट्याख्यम् ।
सूर्याग्रस्याधिक्ये दिग् विपरीताऽत्र विज्ञेया ॥८॥

8. That (*Koṭi*) multiplied by the Moon's diameter and divided by 4 times the *Śaṅku* gives the so called (true) *Koṭi.* When the Sun's *agrā* exceeds the Moon's *agrā*, the direction of the *Koṭi* is to be reversed. (The Rsine of the Moon's altitude similarly reduced is called the true *Bāhu*).

The true *Koṭi* corresponds to the Moon's disc and is in terms of *aṅgulas.*

Thus

$$\text{true } Ko\d{t}i = \frac{\text{Moon's semi-diameter} \times Ko\d{t}i}{\acute{S}a\dot{n}ku} \text{ mins.}$$

$$= \frac{\text{Moon's diameter} \times Ko\d{t}i}{4 \times \acute{S}a\dot{n}ku} \; a\dot{n}gulas \text{ ,}$$

assuming that 1 *aṅgula* = 2 minutes.

GRAPHICAL REPRESENTATION OF THE MOON

पूर्वापरेन्दोरपरत्र दिक्स्थां
कोटिं यथादिक् परिधौ निधाय ।
तन्मत्स्यसूत्रोपरि बाहुमानं
दत्वाऽर्धबिम्बेन लिखेच्छशाङ्कम् ॥९॥

फलमिह कथितं यत् तत्तु विक्षेपजातं
विविधमतिविधेयं चक्रिणं चाम्बुदिग्धम् ।

9-10 (a-b). **Of the Moon lying in the eastern or western hemisphere, the true *Koṭi*, which has already been (calculated and) set down at another place, should be laid off in its own direction. Then, along the head and tail line of the fish-figure drawn at the extremity of that *Koṭi*, should be laid off the (true) *Bāhu*. Thereafter, taking (the extremity of the true *Bāhu* as centre and) the Moon's semi-diameter as radius, one should draw the Moon, which is circular, smeared with water, deflected from the ecliptic, and pertaining to which a variety of results have been set out here.**

SYNOPSIS

इति कथयति देवः पौर्णमासीविधानं
परिणतिवचनौघैश्चारुचन्द्रोदयं च ॥१०॥

10 (c-d). **This is how Deva sets forth briefly and concisely the rules regarding the full moon day as well as the excellent (heliacal) rising of the Moon.**

इति करणरत्ने शृङ्गोन्नत्यधिकारो नाम षष्ठाध्यायः ।

Thus ends Chapter Six of the *Karaṇa-ratna*, dealing with the elevation of the Moon's horns.

CHAPTER 7

POSITIONS OF THE PLANETS

INVOCATION AND INTRODUCTION

गङ्गाम्बुपार्वतीमृगधररेखाधारकः शिवो भवतः ।
रक्षतु सग्रहचारं वक्ष्याम्यार्यभटसदृशफलम् ।।१।।

1. **May God *Śiva* who bears the water of the *Gaṅgā* and the crescent of the Moon on His head and has *Pārvatī* by His side protect you. I shall now describe the rules for calculating the longitudes of the planets along with their motion which will yield results equivalent to those of *Āryabhaṭa*.**

MEAN LONGITUDE OF MARS

द्विष्ठदिनं शिखिशिखिशरशिखिवसुरसपक्ष[२६८३५३३]
भक्तमुपरियुतम् ।
सार्धेन्दुकं[१½]च नगवसुरसो[६८७]द्धृतं मण्डलाद्यारः।।२।।

2. **Set down the *Ahargaṇa* in two places, one below the other. Divide the lower number by 2683533, then add the (resulting) quotient as well as $1\frac{1}{2}$ to the upper number, and then divide that by 687 : the result is the mean longitude of Mars in terms of revolutions etc.**[1]

That is, if A denote the *Ahargaṇa*, then :

$$\text{Mean longitude of Mars} = \frac{A + A/2683533 + 1\frac{1}{2}}{687} \text{ revs.} \qquad (1)$$

1. Similar rules are found to occur also in *PSi* (= *Pañca-siddhāntikā*), xvi. 2 ; *KK* (= *Khaṇḍa-Khādyaka*), I, ii. 1 ; *GCN* (= *Graha-cāra-nibandhana*), i. 23 ; *GCNS* (= *Graha-cāra-nibandhana-saṅgraha*), vs. 10 ; *SMT* (= *Sumati-mahā-tantra*) ; and *KT* (= *Karaṇa-tilaka*).

Rationale.—According to Āryabhaṭa I :

revolutions of Mars in a *yuga* = 2296824,

and civil days in a *yuga* = 1577917500.

$$\therefore \text{ Motion of Mars for 687 days} = \frac{2296824 \times 687}{1577917500} \text{ revs.}$$

$$= 1 + 1/2683533 \text{ revs.}$$

$$\therefore \text{ Motion of Mars for } A \text{ days} = \frac{A + A/2683533}{687} \text{ revs.} \qquad (2)$$

Also, mean longitude of Mars at the epoch ($A = 1384306$)

$$= \frac{2296824 \times 1384306}{1577917500} \text{ revs.}$$

$$= 2015 + \frac{1\frac{1}{2}}{687} \text{ revs.} \qquad (3)$$

From (2) and (3), we evidently get formula (1).

MEAN LONGITUDE OF THE *ŚĪGHROCCA* OF MERCURY

स्वाष्टिवसुमनु[१४८१६]हृताप्तं सकुनिधितिथि[१५९१]
युक्त्वाऽग्निकरण[१३३]गुणितम् ।
दिनमथ खखनगरुद्रै[११७००]र्भक्तं भगणादि-
शशिजोच्चम् ॥३॥

3. **To 133 times the *Ahargaṇa* add the *Ahargaṇa* divided by 14816 plus 1591, and then divide the (resulting) sum by 11700 : the result is the mean longitude of the *Śīghrocca* of Mercury in terms of revolutions etc.**[1]

That is, if A denote the *Ahargaṇa*, then :

Mean longitude of the *Śīghrocca* of Mercury

$$= \frac{133\,A + A/14816 + 1591}{11700} \text{ revs.} \qquad (1)$$

1. Similar rules are found to occur also in *PSi*, xvi. 7; *KK*, I, ii, 2 ; *GCN*, i. 24; *GCNS*; vs. 11; *SMT*; and *KT*.

Rationale. According to Āryabhaṭa I :

revolutions of *Śīghrocca* of Mercury = 17937020,

and civil days in a *yuga* = 1577917500.

∴ Motion of *Śīghrocca* of Mercury for 11700 days

$$= \frac{17937020 \times 11700}{1577917500} \text{ revs.}$$

$$= 133 + 1/14816 \text{ revs.}$$

∴ Motion of *Śīghrocca* of Mercury for A days

$$= \frac{133\,A + A/14816}{11700} \text{ revs.} \tag{2}$$

Also mean longitude of the *Śīghrocca* of Mercury at the epoch ($A = 1384306$)

$$= \frac{17937020 \times 1384306}{1577917500} \text{ revs.}$$

$$= 15736 + \frac{1591}{11700} \text{ revs.} \tag{3}$$

From (2) and (3), we evidenty get formula (1).

MEAN LONGITUDE OF JUPITER

प्रतिदिनमगशशिनिधितिथि[१५९१७]हृतोनितं
रुद्रपावकाक्षि[२३११]युतम् ।
लोचनपावकपावककृत[४३३२]लब्धं मण्डलादिगुरुः ॥४॥

4. Diminish the *Ahargaṇa* by 1/15917 of itself and add 2311, then divide that by 4332 : the result is the mean longitude of Jupiter in terms of revolutions etc.[1]

That is, if A denote the *Ahargaṇa*, then :

$$\text{Mean longitude of Jupiter} = \frac{A - A/15917 + 2311}{4332} \text{ revs.} \tag{1}$$

1. Similar rules are found to occur also in *PSi*, xvi. 2, 4; *KK*, I ii. 3 ; *GCN*, i. 25; *GCNS*, vs. 12 ; *SMT* ; and *KT*.

Rationale. According to Āryabhaṭa I :

revolutions of Jupiter = 364224,

and civil days in a *yuga* = 1577917500.

$$\therefore \text{ Motion of Jupiter for 4332 days } = \frac{364224 \times 4332}{1577917500} \text{ revs.}$$

$$= 1 - 1/15917 \text{ revs.}$$

$$\therefore \text{ Motion of Jupiter for } A \text{ days} = \frac{A - A/15917}{4332} \text{ revs.} \qquad (2)$$

Also, mean longitude of Jupiter at the epoch ($A = 1384306$)

$$= \frac{364224 \times 1384306}{1577917500} \text{ revs.}$$

$$= 319 + \frac{2311}{4332} \text{ revs.} \qquad (3)$$

From (2) and (3), we evidently get formula (1).

MEAN LONGITUDE OF *ŚĪGHROCCA* OF VENUS

रसमनुनिधिनगशशि [१७९१४६] हृतमग्निशर [५३] घ्नदिनगणे रहितम् ।
खनगनगाष्ट [८७७०] युतान्निधिखरन्ध्ररुद्रै [११९०९]-
श्च सितशीघ्रम् ॥५॥

5. **From 53 times the *Ahargaṇa* subtract the *Ahargaṇa* divided by 179146 then add 8770, and then divide by 11909, the result is the mean longitude of the *Śīghrocca* of Venus, in terms of revolutions.**[1]

That is, if A denote the *Ahargaṇa*, then :

$$\text{Mean longitude of } \textit{Śīghrocca} \text{ of Venus} = \frac{53A - A/179146 + 8770}{11909} \text{ revs. } \ldots(1)$$

Rationale. According to Āryabhaṭa I :

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1. Similar rules are found to occur also in *PSi*, xvi. 8; *KK*, I, ii. 4; *GCN*, i. 26; *GCNS*, vs. 13; *SMT*; and *KT*.

Revolutions of *Śīghrocca* of Venus in a *yuga* = 7022388

and civil days in a *yuga* = 1577917500.

∴ Motion of *Śīghrocca* of Venus in 11909 days

$$= \frac{7022388 \times 11909}{1577917500} \text{ revs.}$$

$$= 53 - 1/179146 \text{ revs.}$$

∴ Motion of *Śīghrocca* of Venus in A days

$$= \frac{53\,A - A/179146}{11909} \text{ revs.} \qquad (2)$$

Also, mean longitude of *Śīghrocca* of Venus at the epoch ($A = 1384306$)

$$= \frac{7022388 \times 1384306}{1577917500} \text{ revs.}$$

$$= 6160 + \frac{8770}{11909} \text{ revs.} \qquad (3)$$

From (2) and (3), we evidently have formula (1).

MEAN LONGITUDE OF SATURN

स्वागेन्द्विषुरसरसशशि [१६६५१७] लब्धोनदिनात्
खभूतयमलाङ्गैः [६२५०] ।
वित्र्यंशांशैश्च युताद्रसरसाद्रिखेन्दुभिः [१०७६६] सौरिः ॥६॥

6. **Subtract the *Ahargaṇa* by 1/166517 of itself, then add 6250 minus 1/3, and then divide by 10766 : the result is the mean longitude of Saturn, in terms of revolutions.**[1]

That is, if A denote the *Ahargaṇa*, then :

$$\text{Mean longitude of Saturn} = \frac{A - A/166517 + (6250 - 1/3)}{10766} \text{ revs.} \qquad (1)$$

1. Similar rules are found to occur also in *PSi*, xvi, 3; *KK*, I, ii. 5; *GCN*, i. 27; *GCNS*, vs. 14; *SMT*; and *KT*.

Rationale. According to Āryabhaṭa I :

Revolutions of Saturn in a *yuga* = 146564

and civil days in a *yuga* = 1577917500.

$$\therefore \text{ Motion of Saturn in } 10766 \text{ days } = \frac{146564 \times 10766}{1577917500} \text{ revs.}$$

$$= 1 - 1/166517 \text{ revs.}$$

$$\therefore \text{ Motion of Saturn in } A \text{ days} = \frac{A - A/166517}{10766} \text{ revs.} \qquad (2)$$

Also, mean longitude of Saturn at the epoch ($A = 1384306$)

$$= \frac{146564 \times 1384306}{1577917500} \text{ revs.}$$

$$= 128 + \frac{6250 - 1/3}{10766} \text{ revs.} \qquad (3)$$

From (2) and (3), we evidently have (1).

THE FOUR CORRECTIONS FOR THE PLANETS

मन्दः शीघ्रो मन्दः शीघ्रः क्रमशः स्फुटानि चत्वारि ।
भौमादीनामेवं संस्कारः कथ्यतेऽमुत्र ॥७॥

7. In the case of Mars etc. four corrections are prescribed: *manda-phala*, *śīghraphala*, *mandaphala* and *śīghraphala*, which are to be applied one after another in the order stated (in the manner described below in vss. 13-19).

POSITIONS OF THE ASCENDING NODES

युग[४]यम[२]वसु[८]रस[६]दशका[१०]
दश[१०]गुणिताश्चात्र पातांशाः ।

8(a-b). 4, 2, 8, 6 and 10 each multiplied by 10, are the (longitudes in terms of) degrees of the ascending nodes (of Mars etc.)

These are the same as stated by Āryabhaṭa I.[1]

INCLINATIONS OF THE PLANETS' ORBITS

निधि[९]रवि[१२]रस[६]रवि[१२]रवयो[१२]
दश[१०]गुणितास्तेऽपि परमविक्षेपाः॥८॥

8(c-d). **9, 12, 6, 12 and 12, each multiplied by 10, are the greatest (celestial) latitudes (of Mars etc.) (in terms of minutes).**

These are the same as stated by Āryabhaṭa I.[2]

SPECIAL INSTRUCTION FOR THE SOLAR ECLIPSE

शशिनो हि विक्षेपेऽवनतिः कार्या रवेर्ग्रहणे ।

9(a-b). **While computing a solar eclipse, the Moon's latitude should be corrected for parallax in latitude.**

APOGEES OF THE PLANETS

वसुरुद्रा[११८] दशपक्षाः[२१०] खपुराणाः[१८०]
खनिधयः[९०] षडग्नियमाः[२३६] ॥९॥

9(c-d). **118, 210, 180, 90 and 236 are the (longitudes, in terms of) degrees, of the apogees (of Mars etc.).**

These are the same as given by Āryabhaṭa I.[3]

ŚĪGHROCCA OF MARS, JUPITER AND SATURN

मन्दांशा, रविमध्यं सितबुधयोः शीघ्रमितरेषाम् ।

10(a-b). **The mean Sun is the *Śīghrocca* of the planets other than Mercury and Venus.**

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1. See *Ā*, i. 9(a-b); *KK*, I, viii. 1 (a-b).
2. See *Ā*, i. 8; *KK*, I, viii. 1 (c-d).
3. See *Ā*, i, 9(c-d); *GCN*, 33. The values given in *KK* (I, ii. 6(a-b)) are different from those stated above.

MANDA AND *ŚIGHRA* EPICYCLES

मनु[१४]गिरि[७]गिरि[७]कृत[४]निधयः[९]
परिधय आरतः स्फुटे मन्दे ॥१०॥

विषमे पदेऽथ विद्या[१८]शर[५]वसु[८]यमल[२]-
करणानि[१३] समे ।

त्रिशरे[५३]न्दुबह्नि[३१]रसशशि[१६]निधिशर[५९]-
निधय[९]श्च शीघ्रविषमपदे ॥११॥

शशिशर[५१]नवभुज[२९]तिथयो[१५]
नगशर[५७]वसवः [८]समे प्रोक्ताः ।

10(c-d)-12(a-b) **14, 7, 7, 4 and 9 (respectively) are the *manda* epicycles of the planets Mars etc. for the odd quadrants ; 18, 5, 8, 2 and 13 (respectively), those for the even quadrants.**

53, 31, 16, 59 and 9 (respectively) are the *śīghra* epicycles (of the planets Mars etc.) for the odd quadrants ; 51, 29, 15, 57 and 8 (respectively) are stated to be those for the even quadrants.

These are the same as stated by Āryabhaṭa I.[1] It should be noted that these are not the actual epicycles, but those abraded by $4\frac{1}{2}$.

THE TRUE EPICYCLE

परिधिविश्लेषहता दोर्ज्या त्रिज्योनिता त्वविषमपदे ॥१२॥

त्रिज्यालब्धं सहितं वियुतं न्यूनेऽधिके परिधौ ।

12(c-d)-13(a-b). **(If the planet is in an odd anomalistic quadrant) multiply the difference of the epicycles (for the odd and even quadrants) by the Rsine of the (planet's) anomaly, and if the planet is in an even anomalistic quadrant, multiply the difference of the epicycles by the radius diminished by the Rsine of the**

1. See *Ā*, i. 10-11.

planet's anomaly : and divide (either result) by the radius. Add the quotient to or subtract that from the epicycle of the current quadrant, according as it is smaller or greater than the other. (Thus is obtained the planet's true epicycle.)[1]

THE TRUE LONGITUDE

मन्दोच्चोनितमध्यज्या परिधिघ्ना नगा[७]प्त-
लिप्तार्धम् ।।१३।।

वियुतयुतं गोलवशाद् ग्रहमध्येनोनितं शीघ्रम् ।
तज्ज्या निजपरिधिगुणा दोःकोट्योः खाष्ट[८०]भाजिता
फलदा ।।१४।।

कोटिफलं मध्यपदे त्रिशतै रहितं युतं परे ।
दोर्ज्याफलवर्गयुतात् तद्वर्गात् कीर्तितं पदं कर्णः ।।१५।।

त्रिशतघ्नं बाहुफलं कर्णेनाप्तं धनुष्कार्यम् ।
तस्मान्मन्दोच्चफलं त्यक्त्वा सकलं फलं प्राग्वत् ।।१६।।

गोलवशादानीयाद्रहितं सहितं स्वमूलमध्यं तत् ।
स्फुटमध्यमसंज्ञं स्यात्तृतीयसंस्कारयुक्तं तत् ।।१७।।

तन्निजशीघ्रोच्चोनं स्फुटकेन्द्रं स्याज्ज्ययोः फलं प्राग्वत् ।
दोःकोट्योः पूर्वोक्तन्यायेनानीय कर्णं च ।।१८।।

आनीयात् कर्णफलं तस्मिन् सहितोनितं च तत्कार्यम् ।
उत्तरदक्षिणयोरपि कुजादयः स्युः स्फुटाः सकलाः ।।१९।।

13(c-d)-19. Diminish the mean longitude of the planet by the longitude of its apogee, and find the Rsine thereof. Multiply that (Rsine) by the (planet's true *manda*) epicycle and divide by 7 : apply half of the resulting minutes negatively or positively depending on the (planet's) hemisphere (i. e., according as the planet is

1. *Cf. LBh*, ii. 31-32.

in the half orbit beginning with the anomalistic sign Aries or in that beginning with the anomalistic sign Libra).

Next diminish the longitude of the planet's *Śīghrocca* by the (corrected) mean longitude of the planet, and find the Rsines of the *bāhu* and *koṭi* thereof. Multiply the Rsine of the *bāhu* as well as the Rsine of the *koṭi* by the planet's (true) *śīghra* epicycle and divide (each product) by 80 : the results are the *bāhuphala* and the *koṭiphala*.

The *koṭiphala* should be subtracted from 300 or added to 300, according as the planet is in the second and third (*śīghra* anomalistic) quadrants or in the first and fourth (*śīghra* anomalistic) quadrants. Add the square of that (difference or sum) to the square of the *bāhuphala*, and take the square root (of the resulting sum) : this (square root) is known as the (planet's) hypotenuse.

Multiply the *bāhuphala* by 300 and divide by the (planet's) hypotenuse : and obtain the arc corresponding to the resulting Rsine. (Apply half of the minutes in this arc to the corrected mean longitude of the planet, positively or negatively according as the planet is in the half orbit beginning with the *śīghra* anomalistic sign Aries or in that beginning with the *śīghra* anomalistic sign Libra).

From that subtract the longitude of the planet's apogee, and then obtain the *mandoccaphala* (i.e., the *bāhuphala* due to the planet's apogee), as before, and apply the whole of it to the original (uncorrected) mean longitude of the planet, depending upon the planet's hemisphere (i. e., negatively or positively, according as the planet is in the half orbit beginning with the anomalistic sign Aries or in that beginning with the anomalistic sign Libra). When the abovementioned three corrections have been applied to the planet, it is called the true-mean planet.

Subtract the true-mean longitude of the planet from the longitude of its own *Śīghrocca* : this is the true *śīghra* anomaly. From this (true *śīghra* anomaly) calculate, as before, the *bāhuphala* and the *koṭiphala*. Also find the hypotenuse by using the method stated above. Then obtaining the *karṇaphala*, apply (the whole of) it (to the true-mean longitude of the planet) positively or negatively, according as the planet is in the northern or southern hemi-

sphere (i. e., in the half orbit beginning with the *śīghra* anomalistic sign Aries or in that beginning with the *śīghra* anomalistic sign Libra). This is how the true longitudes of all the planets, Mars etc., are obtained.

Following Āryabhaṭa I, the above rule makes use of the following formulae :

manda anomaly = longitude of planet—longitude of apogee. (1)

$$mandaphala = \frac{300 \sin \theta \times (manda \text{ epicycle})}{7}, \quad (2)$$

where θ is the *bāhu* of the *manda* anomaly.

śīghra anomaly = longitude of *Śīghrocca*—long. of planet. (3)

$$\acute{s}\bar{\imath}ghra\ b\bar{a}huphala = \frac{300 \text{ sign } \theta \times (\acute{s}\bar{\imath}ghra \text{ epicycle})}{80}. \quad (4)$$

where θ is the *bāhu* of the *śīghra* anomaly.

$$\acute{s}\bar{\imath}ghra\ ko\d{t}iphala = \frac{300 \cos \theta \times (\acute{s}\bar{\imath}ghra \text{ epicycle})}{80}. \quad (5)$$

$$\text{hypotenuse} = \sqrt{(300 \pm ko\d{t}iphala)^2 + (b\bar{a}huphala)^2}. \quad (6)$$

$$\acute{s}\bar{\imath}ghra \text{ correction} = \text{arc}\left[\frac{\acute{s}\bar{\imath}ghrab\bar{a}huphala \times 300}{\text{hypotenuse}}\right]. \quad (7)$$

Rationale of formulae (2) and (4).

(1) If θ denote the *bāhu* of the *manda* anomaly, then :

$$mandaphala = \frac{R\sin \theta \times (manda \text{ epicycle})}{80} \text{ mins., where } R = 3438'$$

$$= \frac{300 \sin \theta \times (manda \text{ epicycle})}{\frac{80 \times 300}{3438}} \text{ mins.}$$

$$= \frac{300 \sin \theta \times (manda \text{ epicycle})}{7} \text{ mins.}$$

(2) If θ denote the *bāhu* of the *śīghra* anomaly, then

śīghra bāhuphala $= \frac{300 \sin \theta \times (\textit{śīghra} \text{ epicycle})}{7}$ mins., for the circle of radius 3438′.

$= \frac{300 \sin \theta \times (\textit{śīghra} \text{ epicycle})}{7} \cdot \frac{300}{3438}$ mins., for the circle of radius 300′.

$= \frac{300 \sin \theta \times (\textit{śīghra} \text{ epicycle})}{80}$ mins., for the circle of radius 300′.

Similarly, *śīghra koṭiphala* $= \frac{300 \cos \theta \times (\textit{śīghra} \text{ epicycle})}{80}$ mins.

SYNOPSIS

ग्रहमध्यं पातांशं परमविक्षेपमपि च मन्दोच्चम् ।
परिधिं कर्णं चापं ग्रहस्फुटं चाह देवोऽत्र ॥२०॥

20. In this chapter Deva has dealt with the following topics : mean longitudes of the planets, degrees (of longitude) of the ascending nodes, inclinations of the planetary orbits (lit. greatest latitudes), positions of the apogees, epicycles, hypotenuse, arc (corresponding to the given Rsine), and correction of the planets.

इति करणरत्ने ग्रहचाराधिकारः सप्तमोऽध्यायः ।

Thus ends Chapter Seven of the *Karaṇa-ratna*, dealing with the Planetary Motion.

CHAPTER 8

PLANETARY MOTION AND PLANETARY CONJUNCTION

HELIACAL RISING AND SETTING

भ[२७]मनु[१४]नखां[२०]शैः कुजगुरुशनयः केन्द्रैः
पुरन्दराशायाम् ।
उदयं कुर्युश्च तदा तद्वच्चक्रे विहीनेऽस्तम् ॥१॥

नन्दशरै[५९]रपरदिशो बुध उदयं नगशरेन्दु[१५७]भिश्चास्तम् ।
रुद्रभुजैः[२११]प्रागुदयं शून्याकाशाग्नि[३००]भिश्चास्तम् ॥२॥

भृगुजः पश्चादुदयं जिनै[२४]र्नगागेन्दु[१७७]भिस्तथा चास्तम् ।
प्रागुदयं त्रिपुराणै[१८३]र्नगहुतभुक्पावकै[३३७]रस्तम् ॥३॥

1. At 27, 14 and 20 degrees (respectively) of (*śīghra*) anomaly, Mars, Jupiter and Saturn rise in the east : and at 360° diminished (respectively) by the same (degrees), they set (in the west).

2. At 59°, Mercury rises in the west : at 157°, it sets (in the west) : at 211°, it rises in the east ; and at 300°, it sets (in the east).

3. Venus rises in the west at 24°, and sets (in the west) at 177°. It rises in the east at 183° and sets (in the east) at 337°.

COMMENCEMENT AND CONCLUSION OF REGRESSION

स्वरशशि[१७]शिखिशिखि[३३]शशिशर[५१]-
शरशशि[१५]शररस[६५]विहीनचक्रार्धे ।
केन्द्राख्ये भौमाद्या वक्रिण एतैर्युतैर्मुक्ताः ॥४॥

4. **At 180° diminished (respectively) by 17, 33, 51, 15 and 65 (degrees) of (*śīghra*) anomaly, Mars etc. take up retrograde motion ; and at 180° increased (respectively) by the same (degrees), they abandon it.**

The following tables exhibit the planetary motion described in the above verses more clearly. The corresponding degrees of *śīghra* anomaly stated in the *Khaṇḍa-khādyaka* are also given for the facility of comparison.

Table 13. Motion of Mars

śīghra anomaly given by Deva	Phenomenon	*śīghra* anomaly given in *KK*, I, ii. 8-9
27°	Rises in the east	28°
163°	Retrograde motion begins	164°
197°	Retrograde motion ends	196°
333°	Sets in the west	332°

Table 14. Motion of Mercury

śīghra anomaly given by Deva	Phenomenon	*śīghra* anomaly given in *KK*, I, ii-10-11
59°	Rises in the west	51°
147°	Retrograde motion begins	146°
157°	Sets in the west	155°
211°	Rises in the east	205°
213°	Retrograde motion ends	214°
300°	Sets in the east	309°

Table 15. Motion of Jupiter

śīghra anomaly given by Deva	Phenomenon	*śīghra* anomaly given in *KK*, I, ii-12-13
14°	Rises in the east	14°
129°	Retrograde motion begins	130°
231°	Retrograde motion ends	230°
346°	Sets in the west	346°

Table 16. Motion of Venus

śīghra anomaly given by Deva	Phenomenon	*śīghra* anomaly given in *KK*, I, ii-14-15
24°	Rises in the west	24°
165°	Retrograde motion begins	165°
177°	Sets in the west	177°
183°	Rises in the east	183°
195°	Retrograde motion ends	195°
337°	Sets in the east	336°

Table 17. Motion of Saturn

śīghra anomaly given by Deva	Phenomenon	*śīghra* anomaly given in *KK*, I, ii 16-17
20°	Rises in the east	20°
115°	Retrograde motion begins	116°
245°	Retrograde motion ends	244°
340°	Sets in the west	340°

MEAN DAILY MOTION

शशिगुण[३१]रसकृतलोचन[२४६]-
विषया[५]ङ्गच्छिद्र[९६]बाहवो[२] लिप्ताः ।
भौमादिमध्यगतयः सितबुधयोः सा तु शीघ्रगतिः ॥५॥

प्रथमाध्याये कथिता रविचन्द्रमसोः, क्रमेण भुक्तिः स्यात् ।
इन्दूच्चस्य च राहोर्भुक्तिर्मुनयो[७]ऽग्नय[३]श्चेति ॥६॥

5. 31′, 246′, 5′, 96′ and 2′ (respectively) are the mean daily motions of Mars etc. In the case of Mercury and Venus, the motions pertain to their *Śīghroccas*.

6. The mean daily motions of the Sun and Moon are the same as stated in the first chapter.[1] Of the Moon's apogee and the Moon's ascending node, the mean daily motions are 7′ and 3′ respectively.

TRUE DAILY MOTION

स्वस्वस्फुटवृत्तगुणां मध्यगतिं मन्दखण्डजीवाघ्नाम् ।
खषडिन्दुसागरै[४१६०]स्तां विभजेल्लब्धं फलं योज्यम् ॥७॥

मध्यपदे स्वे भोगे ह्याद्यन्तपदे फलं तु तत् त्याज्यम् ।
सा मध्यस्फुटभुक्तिः स्वशीघ्रभुक्त्यूनिता भवति ॥८॥

शीघ्रफलभोगवर्गाद्रामाक्ष्या[२३]प्तफलैर्युतं कर्णः ।
तत्त्रिज्याविवरकलाहता भवेच्छीघ्रभुक्त्यूना ॥९॥

यद्विभजेच्छ्रवणेन प्राप्तफलं योजयेत् स्वमन्दगतौ ।
कर्णेऽधिके त्रिशत्या ऊने कर्णे तु तत्त्याज्यम् ॥१०॥

वक्रसमये ग्रहाणां स्फुटगतिविषये विपर्ययो भवति ।

1. See *supra*, i, 31(a-b). p. 22.

उभयत्रापि धनर्णे व्यस्तेऽन्यत् सर्वमेवं स्यात् ॥११॥

कथितैवं स्फुटभुक्तिर्भौमादेः ग्रहगणितविद्भिः ।
मध्यगतिरेव राहोरुच्चस्य च कथ्यते तद्वत् ॥१२॥

7-12. **Multiply the mean daily motion (of the planet) by its own true (*manda*) epicycle as well as by the (current) Rsine-difference of *manda* anomaly and divide by 4160[1]. The resulting quantity should be added to its own mean daily motion (when the planet is) in the middle (anomalistic) quadrants ; (when the planet is) in the first and last (anomalistic) quadrants, that quantity should be subtracted (from the mean daily motion). This (sum or difference) is the planet's true-mean daily motion. Subtract it from the daily motion of its *Śīghrocca* : (the result is known as the *śīghra-kendra-gati*). Divide the square of the *śīghraphala-gati* by 23 and add it to (or subtract it from) the (planet's) hypotenuse (as the case may be) : (the result is the true hypotenuse). By the minutes of difference of that (true hypotenuse) and the radius, multiply the *śīghrakendra-gati* and divide that by the (true) hypotenuse. Add the resulting quantity to the true-mean daily motion, provided the hypotenuse is greater than the radius ; if the hypotenuse is smaller than the radius, subtract that (from the true-mean daily motion) : the result is the true daily motion of the planet.**

When the planet is retrograde, there is difference in the procedure for finding its true daily motion. In both the places (where addition and subtraction have been prescribed above), the law of addition and subtraction should be reversed : the rest should be taken as it is.

This is how the learned scholars of astronomy state the method for finding the true daily motion of Mars., etc.

In the case of the Moon's ascending node, the mean daily motion itself is the true daily motion. The same is also said (to be true) for the Moon's apogee.

1. The correct number is 4190.

The above rule is generally the same as that found to occur in the *Sūrya-siddhānta*[1] and the *Vṛddha-vasiṣṭha-siddhānta*[2]. The correction for the hypotenuse prescribed in the above rule, however, has no counterpart in any other known work on Hindu astronomy.

CONJUNCTION OF PLANETS

गत्यधिकहीनभावाच्छीघ्रो मन्दो भवेद्ग्रहश्च सदा ।
शीघ्रेऽधिके गतः स्यादेष्यो मन्देऽधिके योगः ।।१३।।

ज्ञात्वाऽनयोः समागमकालमथासन्नयोगिनोरुभयोः ।
अधिकादल्पं हित्वा लिप्तीकृत्वाऽन्तरं विभजेत् ।।१४।।

भुक्त्यन्तरेण लब्धं फलमन्तरजं दिनानि योगेन ।
वक्रगतावथ भुक्त्या पृथक् पृथक् ताडयेदनयोः ।।१५।।

अथ तं विभजेत् षष्ट्या लब्धफलं लिप्तिकास्तु विज्ञेयाः ।
यदि चरतः समगत्या हेया देया गतेऽगते तत्र ।।१६।।

हेयधनं विपरीतं वक्रगतौ चेत्स्थितस्तयोरेकः ।
इति समलिप्ताभावः समासतः सूरिभिः ख्यातः ।।१७।।

13. A planet is said to be faster or slower (than another planet), according as its velocity is more or less (than that of the other).

If the faster of the two planets has greater longitude, (it should be inferred that) the conjunction of the two planets has already occurred. If (on the other hand) the slower of the two planets has greater longitude, (it should be understood that) the conjunction of the two planets is to occur.

14-17. When one comes to know that the time of conjunction of two planets, in close vicinity, is about to occur one should subtract

1. ii. 48(c-d)-51(a-b).
2. ii. 25-28.

the planet with smaller longitude from the planet with greater longitude and reduce the difference to minutes. One should then divide that difference (in terms of minutes) by the difference of the daily motions (of the two planets) (in case both the planets are in direct motion) or by the sum of the daily motions (of the two planets) if either of the two planets is in retrograde motion : one should then severally multiply the resulting days, arising from the difference of the two planets, by the daily motions of the two planets and divide[1] (each product) by 60 : the result is in terms of minutes. If the two planets are in direct motion, these minutes should be subtracted from or added to the longitudes of the respective planets, according as the conjunction has occurred or is to occur. If either of the two planets is retrograde, subtraction and addition should be reversed for this planet.

This is in brief the method stated by the learned for the equalisation of the longitudes of two planets.

The conjunction of the planets is known by different names. The conjunction of a planet with the Sun is called 'heliacal setting' (*astamaya*) ; the conjunction of a planet with the Moon is called 'union' (*samāgama*) ; and the conjunction of any two planets other than the Sun and Moon is called 'encounter' (*yuddha*).

THE ITERATION PROCESS

प्राग्वत् सवर्णयित्वा स्फुटभुक्त्या तद्दिनानि सङ्गुण्य ।
षष्ट्या हृत्वा तत्फलमानीयादृणं धनं तद्वत् ॥१८॥
एवं क्रियया विधिवत् संस्कृत्य पृथक् पृथक् क्षिपेच्छोध्यम् ।

18-19(a-b). **Again reduce the difference of the longitudes of the two planets to minutes, as before ; (then find the corresponding days) ; then (severally) multiply those days by the true daily motions of the two planets and divide by 60; and then subtract the (resulting) quotients from or add them to the longitudes of the respective planets, as**

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1. This division by 60 is not correct.

before. Proceeding in this way, correct the longitudes of the two planets by adding and subtracting the motions of the respective planets.

THE CELESTIAL LATITUDE

तत्कालस्फुटमध्यात् पातोनाच्छनिकुजाङ्गिरसाम् ॥१९॥
सितबुधयोः शीघ्रोच्चाद् बाहुज्यां गुणितपरमविक्षेपः ।
विक्षेपः श्रुतिलब्धः,

19(c-d)-20 (a-c). **Subtract the longitude of the planet's ascending node from the instantaneous longitude of the true-mean planet in the case of Mars, Jupiter and Saturn, and from the longitude of the planet's *Śīghrocca* in the case of Mercury and Venus ; and then multiply the Rsine of the *bāhu* of the remainder by the (planet's) greatest latitude and divide by the (planet's *śīghra*) hypotenuse : the result is the (planet's instantaneous) latitude.**[1]

DISTANCE BETWEEN PLANETS IN CONJUNCTION

स्फुटक्रियार्थं समान्यदिशोः ॥२०॥
रहितः सहितः कार्यस्त्वेकैकस्मिन् क्रमेण विक्षेपः ।
अन्तरमब्धि[४]प्रहृतम् अङ्गुलयः स्युः ग्रहान्तरजाः ॥२१॥

20(d)-21. **To obtain the true distance between (the centres of) the two planets (when they are in conjunction in longitude), one should take the difference or sum of the latitudes of the two planets, according as they are of like or unlike directions.**[2] **The (resulting) sum or difference divided by 4 gives the distance between (the centres of) the two planets in terms of *aṅgulas*.**

THE VICTOR

उभयोरेकत्रगयोः तदा जयत्यधिकविष्कम्भः ।
उभयोरुत्तरगोले विक्षेपेणाधिकस्तदा जयति ॥२२॥

1. *Cf. KK*, I, viii. 5.
2. *Cf. KK*, I, viii. 6(a-b).

उभयोर्दक्षिणगोले तदा जयत्यूनविक्षेपः ।
भिन्नायामाशायामुत्तरगोलस्तदा जयति ॥२३॥

22. **When the two planets are together, the planet with greater diameter is the victor. When both the planets are to the north of the ecliptic, the planet with greater latitude is the victor.**

23. **When both the planets are to the south of the ecliptic, the planet with lesser latitude is the victor. When the latitudes of the two planets are of different directions, the planet with north latitude is the victor.**

The above rules show that, in general, the planet which lies to the north of the other is the victor. But Venus is always the victor, no matter whether it lies to the north or south of the other planet.

SYNOPSIS

उदयास्तमये वक्रं स्फुटभुक्तिं लिप्तिकासमानत्वम् ।
अङ्गुलविक्षेपजयाजयांश्च देवोऽत्र निजगाद ॥२४॥

24. **In this chapter Deva has described : heliacal rising and setting, retrograde motion, true daily motion, equalisation of the longitudes of two planets up to minutes, latitude in *aṅgulas*, as well as victory and defeat of the planets.**

इति देवाचार्यकृतौ करणरत्ने ग्रहयुद्धाधिकारोऽष्टमोऽध्यायः ।[1]

Thus ends Chapter Eight, dealing with the Planetary Conjunction, in Devācārya's *Karaṇa-ratna.*

1. After this colophon the manuscript reads : सप्तषष्ट्युत्तरशतपरिमितिः ।

APPENDIX 1

CHAPTER ON *MAHĀPĀTA* ASCRIBED TO *KARAṆA-RATNA*

VAIDHṚTA AND *VYATĪPĀTA*

एकायनगतौ स्यातां सूर्याचन्द्रमसौ यदा ।
तद्युतौ मण्डले क्रान्त्योः साम्यत्वे वैधृताभिधः ॥१॥[1]

विपरीतायनगतौ चन्द्राकौं क्रान्तिलिप्तिकाः ।
समास्तदा व्यतीपातो भगणार्धे तयोर्युतौ ॥२॥[2]

1. **When the Sun and Moon are in the same *ayana* (i. e., on the same side of a solstice), the sum of their longitudes amounts to a circle (i. e., 360°) and their declinations are equal, the phenomenon is called *Vaidhṛta* (or *Vaidhṛti*). [Also see *infra*, vs. 54 (c-d)]**

2. **When the Sun and Moon are in different *ayanas* (i. e., on the different sides of a solstice), the number of minutes in the declination of each of them is the same, and the sum of their longitudes amounts to half a circle (i. e., 180°), the phenomenon is called *Vyatīpāta*. [Also see *infra*, vss. 41, 54(a-b)]**

RECAPITULATION

एकायने भिन्नदिशो रवीन्द्वोः भुजासमत्वं यदि वैधृतिः स्यात् ।
यदा च भिन्नायनगे रवीन्द्वोः समानदिक्त्वं व्यतिपातयोगः ॥३॥[3]

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1. Verse 1 has been taken from the *Sūrya-siddhānta*, with the word तुल्यत्वे replaced by साम्यत्वे. See *SūSi*, xi. 1.
2. Verse 2 has been taken from the *Sūrya-siddhānta* without any alteration. See *SūSi*, xi. 2.
3. Verses printed in smaller black types occur in MS. C but not in MS. B.

3. **When the Sun and Moon, lying in the same *ayana*, have declinations of unlike directions but equal *bhujās* (of the longitudes), the phenomenon is called *Vaidhṛti*; and when the Sun and Moon, lying in different *ayanas*, have (equal) declinations of like directions, the phenomenon is called *Vyatipāta*.**

It is noteworthy that whereas verse 1, which has been taken from the *Sūrya-siddhānta*, uses the masculine form *Vaidhṛta*, verse 3 uses the feminine form *Vaidhṛti*. Similarly, whereas verse 2, which also has been taken from the *Sūrya-siddhānta* uses the form *Vyatīpāta*, verse 3 uses the form *Vyatipāta*.

NEAR THE EQUINOX AND THE SOLSTICE

रवीन्द्वोः साम्यता क्रान्त्योः विषुवत्सन्निधौ यदा ।
द्विर्भवेद्द्विस्तदा पातः स्यादभावो विपर्यये ॥४॥[1]

4. **When the Sun and Moon are near an equinox and the equality of their declinations occurs twice, then there occurs a *Pāta*-pair (called "*Dvirbhava Pāta*"). [Also see *infra*, vss. 7, 8]. In the contrary case (i. e., when the Sun and Moon are near a solstice and the equality of their declinations does not occur), there is absence of a *Pāta*. [Also see *infra*, vss. 6, 8, 21-22]**

The former case occurs when the Moon's latitude is small enough See *infra*, vs. 8. The latter case occurs when the Moon's true declination is smaller than the Sun's declination. See *infra*, vs. 55.

DAYS ELAPSED OR TO ELAPSE

चलांशयुक्तो रविचन्द्रयोगो भार्धेन चक्रेण समो यदा स्यात् ।
यदाऽधिकोनो गतगम्यलिप्ताः तद्भुक्तियोगेन
भजेद् दिनादिकम् ॥५॥

5. **When the sum of the longitudes of the Sun and Moon, corrected for the precession of the equinoxes, amounts to half a circle (i. e., 180°) or a circle (i. e., 360°), (a *Pāta* takes place). When that**

1. Verse 4 has been taken from the *Sūrya-siddhānta*, with the word तुल्यता replaced by साम्यता and विपर्ययात् by विपर्यये. See *SūSi*, xi. 19.

sum is greater or less than that, divide the minutes of the excess or defect by the motion-difference of the Sun and Moon : the quotient gives the days etc. (elapsed since or to elapse before the occurrence of a *Pāta*).

ABSENCE OF *PĀTA*

वीणासिंहायनयोः कार्मुककुम्भायनयोश्च सूर्ये ।
मृगकर्क्यादौ चन्द्रे पाताभावः तदा ज्ञेयः ॥६॥

6. **When the Sun lies in the house of Gemini or Leo, or in the house of Sagittarius or Aquarius, and the Moon in the beginning of Capricorn or Cancer, absence of *Pāta* should be understood.[1] [Also see *supra*, vs. 4 ; *infra*, vss. 10, 21-22, 55]**

It is presumed in the above rule that the true declination of the Moon is less than the declination of the Sun. See *infra*, vs. 55.

DVIRBHAVA OR DOUBLE *PĀTA* AND TERRIBLE *PĀTA*

विषुवत्सन्निधावेव द्विर्भवः परिकीर्तितः ।
स्थित्यर्धनाडिकानां तु बहुत्वे घोरसंज्ञकः ॥७॥

7. **When the Sun and the Moon are near an equinox, a *Dvirbhava Pāta* is said to occur. [Also see *supra*, vs. 4]. And when the number of *nāḍīs* in the semi-duration of *Pāta* is large, the *Pāta* is called *ghora* or terrible. [Also see *infra*, vs. 10]**

DVIRBHAVA PĀTA AND ABSENCE OF *PĀTA*

इन्दोः भुजज्या फणिजीवहीना
पातद्वयं स्यात् विषुवत्समीपे ।
पातो हि न स्यादयनाच्च पूर्वे
त्रयोदशाहे न पुनश्च पातः ॥८॥

1. For a similar rule see *KK*, I, i. 13.

8. When the Ṛsine of the *bhuja* of (the longitude of) the Moon is less than the Rsine of (the longitude of) the Moon's ascending node, a *Dvirbhava* or double *Pāta* occurs near an equinox. [Also see *supra*, vs. 4]. The phenomenon of *Pāta* does not occur prior to a solstice, and also within thirteen days after that. [Also see *supra*, vs. 6; *infra*, vss. 10, 18, 22(c-d), 24, 53]

THE FIVE VARIETIES OF *PĀTA*

स्फुटपातो ह्यभावश्च सामान्यो द्विर्भवस्तथा ।
घोरपात इति ख्याताः पञ्चपाताः प्रकीर्तिताः ॥९॥

स्फुटं स्यात् चक्रचक्रार्धे सामान्यं रुद्रपञ्चके ।
अभावं धनुयुग्मादिद्वयोः घोरं दिनार्धके ॥१०॥

9. The five well known varieties of *Pāta* are : (1) the true *Pāta*, (2) absence of *Pāta*, (3) the ordinary *Pāta*, (4) the *Dvirbhava Pāta*, and (5) the terrible *Pāta*.

10. The true *Pāta* occurs when the sum of the longitudes of the Sun and Moon amounts to a circle (i e., 360°) or half a circle (i.e., 180°); the ordinary *Pāta* (i.e., *Sārpamastaka Vyatīpāta*) occurs at the end of the sixteenth *yoga* (i.e., when the minutes of the sum of the longitudes of the Sun and Moon, divided by 800, yields 16 as the quotient); there is absence of *Pāta* (when the Sun is) in the two sign-couplets—Sagittarius and Aquarius, Gemini and Leo, (and the Moon in the beginning of the sign Capricorn or Cancer). [See *supra* vss. 6, 8; *infra*, vss 21-22, 55]; and the terrible *Pāta* occurs at midday. [See *supra*, vs. 7].

The term *rudrapañcaka* means 16, because *rudra* (11)+*pañcaka* (5)= 16.

In finding the ordinary *Pāta* i.e., the *Vyatīpāta yoga*, one should not apply precession of the equinoxes to the longitudes of the Sun and Moon.

PRECESSION OF THE EQUINOXES

शशिलोचनवेदो [४२१] नशाकमङ्कैः [९] विवर्धितम् ।
खखतर्कैः [६००] हृतं लब्धम् अयनांशफलं भवेत् ॥११॥

11. **Subtract 421 from the *Śaka* year, then multiply by 9, and then divide by 600 : the result is the precession of the equinoxes (in terms of degrees).**

Whereas vs. 36 of the first chapter of the *Karaṇa-ratna* gives the rate of precession of the equinoxes as 47″ per annum, this verse gives the same as 54″ per annum. This discrepancy clearly shows that this verse cannot be a composition of Deva.

APPLICATION OF THE PRECESSION

अयनांशाः प्रदातव्याः लग्नक्रान्तिचरादिषु ।
ग्रहपाते त्रिषु क्षिप्य दिवानाथेन्दुराहुषु ॥१२॥

12. **The precession of the equinoxes is to be applied in finding : the longitude of the rising point of the ecliptic, the declination, the ascensional difference, and so on. In the case of eclipse and *Pāta* it should be applied to all the three—the Sun, Moon, as well as *Rāhu*.**

YOGAS ASSOCIATED WITH *VYATIPĀTA* AND *VAIDHṚTI*

गण्डोत्तरार्धं प्रभृति पञ्चसु व्यतिपातकः ।
वैधृतिः शुक्लयोगादौ नियतः सार्धपञ्चके ॥१३॥

13. **The *Vyatipāta* occurs within the duration of the five *yogas* beginning with the second half of *Gaṇḍa* ; and the *Vaidhṛti* undoubtedly occurs within the duration of the four and a half *yogas* beginning with *Śukla*. [Also see *infra*, vss. 17, 23]**

Gaṇḍa is the tenth *yoga* and *Śukla* the twenty-fourth. For the complete list of twenty-seven *yogas*, see *supra* p. 32.

Had the *Pātas* been calculated from the true longitudes of the Sun and the Moon, without applying precession of the equinoxes to them, *Vyatīpāta* would have occurred in the middle of the *yoga Harṣaṇa* and *Vaidhṛta* at the end of the *yoga Vaidhṛta*. But since in the computation of the *Pātas*, precession of the equinoxes is applied to both the Sun and the Moon it would not be the case. Since the maximum value of precession applied to the Sun and Moon is $\pm 54^{\circ}$ which corresponds to $\mp 4\frac{1}{2}$ *yogas*,

Vyatīpāta may occur in the 9 *yogas* beginning with *Gaṇḍa,* and *Vaidhṛta* in the 9 *yogas* beginning with *Śubha.* (See vs. 23). Yallaya, commenting on *SūSi*, xi. 19, says :

'The (*Vyatī*) *pāta* may occur in the four *yogas* preceding or following the middle of *yoga Harṣaṇa*, according as the precession of the equinoxes is positive or negative. And *Vaidhṛti* in the four *yogas* preceding or following the end of *yoga Vaidhṛti.* (It is therefore said) :

> "The *Vyatīpāta* is possible in the 8 *yogas* beginning from the second half of *Gaṇḍa* and the *Vaidhṛta* in the 8 *yogas* beginning with *Śukla.*"[1]'

COMPUTATION OF *PĀTA*

नान्यदाऽसौ सम्भवत्येव, ततः प्रागेव साधयेद् ।
चन्द्रार्कराहून् संशुद्धान् सायनांशान् द्विजोत्तमः ॥१४॥

चन्द्रार्कयोः क्रान्तिलवाः क्षेपो राहूनचन्द्रतः ।
चन्द्रक्रान्तौ क्षेपभागान् गोलैक्ये योजयेत् सुधीः ॥१५॥

भिन्नगोले वियुञ्जीत अधिक्षेपे वियोजयेत् ।
पदान्यत्वं विधोः कल्प्यं युग्मौजभेदतः ॥१६॥

14. **It does not occur anywhere else. So prior to its occurrence the best amongst the *Dvijas* should calculate the true longitudes of the Moon, Sun and *Rāhu* (i. e., Moon's ascending node), as corrected for the precession of the equinoxes.**

15. **He should calculate also the degrees of the declinations of the Sun and Moon, and, from the longitude of the Moon diminished by that of its ascending node, the celestial latitude of the Moon. The intelligent (astronomer) should then add the degrees of the Moon's latitude to (the degrees of) the Moon's declination, provided they are of the same hemisphere (north or south).**

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1. पात्तो हर्षणार्धात् प्राक्पश्चाद्योगचतुष्टये, स्वर्णाख्येऽयनांशेषु वैधृत्यन्ताच्च वैधृतिः ।
गण्डोत्तरार्धात् व्यतिपातसम्भवः, शुक्लादितो वैधृतिसम्भवः स्यात् ॥

16. When they are of different hemispheres, the former should be subtracted from the latter. In case the Moon's latitude is greater, subtraction should be made from the former. But in this case, the quadrant of the Moon should be reversed, i.e., it should be taken as even when odd, and odd when even.[1] [Also see *infra*, vss. 38, 40]

RECAPITULATION OF THE *YOGAS* ASSOCIATED WITH *PĀTA*

गण्डोत्तरार्धाद् व्यतिपातसंज्ञं शुक्लादितो वैधृतिसंज्ञमाहुः ।
चन्द्रा[र्कयोः] क्रान्तिसमानयोगे शुभानि वर्ज्यानि मुनयो वदन्ति ।।१७।।

17. (The *Pāta* which occurs in the five *Yogas* commencing) from the second half of the *yoga Gaṇḍa* is called *Vyatipāta* and (the *Pāta* which occurs in the four and a half *yogas* commencing) from the *yoga Śukla* is called *Vaidhṛti*, provided the declinations of the Sun and Moon happen to be the same. These are prohibited for good deeds. This is what the sages say. [See *supra*, vs. 13 ; *infra*, vs. 23]

RECURRENCE OF *PĀTA*

खाब्धिमातंग[८४०]घटिकाः परे पातप्रवेशनम् ।
चतुर्दश[१४]दिनानां तु पातस्य भ्रमणं पुनः ।।१८।।

18. *Pāta* may occur again after 840 *ghaṭīs*, because the period (for the recurrence) of a *Pāta* is 14 days. [See *infra*, vss. 21-22, 24, 53.]

MOON'S ASCENDING NODE

सुगंधिजलमुख्यो[१५३८९३७]नं द्युगणं गुणिना[५३]हृतम् ।
अनूनकै[१०००]र्लब्धमंशं राहुश्चक्राच्च्युतो भवेत् ।।१९।।

19. Deduct 1538937 from the *Ahargaṇa*, then multiply by 53, and then divide by 1000 : the resulting degrees subtracted from a circle give the longitude of the Moon's ascending node (*Rāhu*).

According to Āryabhaṭa I :

Revolution-number of Moon's asc. node = 232226

1. *Cf. VāK* (= *Vākya-karaṇa*), v. 12 (c-d).

and civil days in a *yuga* = 1577917500.

$$\therefore \text{mean daily motion of Moon's asc. node} = \frac{232226}{1577917500} \text{ revs.}$$

$$= \frac{232226 \times 360}{1577917500} \text{ degrees}$$

$$= \frac{53}{1000} \text{ degrees approx.}$$

Hence the above rule.

Subtraction from a circle is prescribed because the longitudes are measured eastwards whereas the Moon's ascending node moves westwards.

The *Ahargaṇa* 1538937 corresponds to A. D. 1112. This is evidently the time when this rule was devised. The above verse is obviously not a composition of Deva, who flourished in A. D. 689.

NORTHERN AND SOUTHERN HEMISPHERES AND *AYANAS*

मेषादिरुत्तरविशा यमदिक् तुलादिः ।[1]
कर्क्यादि याम्यमयनं मकरादि सौम्यम् ॥२०॥

20. **The northern hemisphere begins with the first point of Aries ; and the southern hemisphere, with the first point of Libra. The southern *ayana* begins with the first point of Cancer ; and the northern *ayana*, with the first point of Capricorn.[2] [Also see *infra*, vs. 31]**

ABSENCE AND RECURRENCE OF *PĀTA*

मिथुनायनमारभ्य सिंहायनमतः परम् ।
धनुरायनमारभ्य कुम्भायनमतः परम् ॥२१॥

पाताभावस्य कालोऽयम् इत्युक्तं दैववित्तमैः ।
पातस्त्रयोदशाहोभिः वैधृतिः स्यात् चतुर्दशे ॥२२॥

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1. Verse 20(a-b) is the same as *KR* (= *Karaṇa-ratna*), i. 38(a-b).
2. *Cf. MSi* (= *Mahā-siddhāntā*), iii. 37.

पुनः चन्द्रार्कयोः क्रान्त्योः साम्ये पातस्य सम्भवः ।
गण्डादिपञ्चके पातः शुभाद्ये पञ्च वैधृतिः ॥२३॥

अन्यथा न हि योगं च पुनर्योगं चतुर्दशे ।
विष्कम्भे वैधृतौ वज्रे व्याघाते हर्षणे तथा ॥२४॥

चन्द्रे चार्कस्य सङ्क्रान्तिसाम्ये पातस्य सम्भवः ॥२५॥

क्रान्तिर्विधोरोजपदेऽधिकोना क्रान्तेर्दिनेशस्य गतैष्यपातम् ।
युग्मेऽधिकोना भविता गतः स्यात् विक्षेपशेषे तु पदान्यथा स्यात् ॥२६॥

युग्मपादादिगस्येन्दोः क्रान्तिसाम्ये युतायुते ।
ओजपादान्तसूर्यस्य क्रान्तेः पातो न जायते ॥२७॥

21-22. From the sign of Gemini to the sign of Leo, and from the sign of Sagittarius to the sign of Aquarius—this is the domain in which the phenomenon of *Pāta* fails to take place. [See *supra*, 4, 6, 8 10; *infra*, vs. 55]. This is what the best amongst the astronomers say. The (next)) *Pāta* occurs after 13 days, and (so after the occurrence of a *Vyatipāta*) *Vaidhṛti* occurs on the 14th day. [See *supra*, vss. 8, 18; *infra*, vss. 24, 53]

23. When the declinations of the Sun and Moon are again equal, there is a possibility of the occurrence of a *Pāta*. The (*Vyati*)*pāta* occurs within the five *yogas* commencing with *Gaṇḍa*, and the *Vaidhṛti* within the five *yogas* commencing with *Śubha*. [See *supra*, vss. 13, 17]

This teaching is slightly different from that of stanzas 13 and 12; but quite different from that of stanzas 24 and 32.

24. This does not happen otherwise. But, after the occurrence of one *Pāta* the next *Pāta* occurs on the 14th day, *Vaidhṛti* during (the *yoga*) *Vaidhṛti* or *Viṣkambha*, and *Vyatipāta* during (the *yoga*) *Vyāghāta*, *Harṣaṇa*, or *Vajra*. [See *infra*, vs. 32]

25. A *Pāta* is possible when the declinations of the Moon and the Sun are equal.

26. It should be deemed to have (already) occurred or to occur, according as the Moon's (true) declination is greater or less than that of the Sun, provided the Moon is in an odd quadrant. When the Moon

is in an even quadrant, it should be deemed to occur or to have occurred, (respectively). When the Moon's latitude exceeds its declination, the quadrants should be reversed.[1]

27. **When the Moon is in the beginning of an even quadrant, equality of declinations of the Sun and Moon has either occurred or will occur. But if the Sun is at the end of an odd quadrant, equality of declinations of the Sun and Moon does not occur. [Also see *infra*, vs. 55]**

BHUJA FROM *KENDRA*

केन्द्रे त्रिभादनधिके सति दोस्तदेव राशित्रयात्समधिके पतिते भषट्कात् ।
षड्भोनिते षडधिके रहिते भचक्रान्नन्दाधिके भवति बाहुरिहावशेषः ॥२८॥[2]

28. **When the *kendra* does not exceed 3 signs, the *bhuja* (of the *kendra*) is the same as the *kendra* ; when the *kendra* exceeds 3 signs, the *bhuja* (of the *kendra*) is equal to 6 signs minus the *kendra* ; when the *kendra* exceeds 6 signs, the *bhuja* (of the *kendra*) is equal to the *kendra* minus 6 signs ; and when the *kendra* exceeds 9 signs, the *bhuja* (of the *kendra*) is equal to a circle (i. e., 12 signs) minus the *kendra*. [Also see *infra*, vs. 29]**

REPETITION OF THE SAME RULE

केन्द्रे त्रिभाच्च नवभाऽयूनादोजपदं भवेत् ।
अधिके युग्मसंज्ञं स्यात् षड्भाच्चक्राद्विशोधयेत् ॥२९॥

29. **When the *kendra* is less than 3 signs or 9 signs, the quadrant is odd; when greater, the quadrant is even. When the *kendra* is greater than 3 signs, it should be subtracted from six signs; (when greater than six signs, 6 signs should be subtracted from it); when greater than 9 signs, it should be subtracted from a circle (i.e., 12 signs): (the result is the corresponding *bhuja*).**

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1. *Cf. SūSi*, xi. 7-8 ; *KK*, II, i. 15 ; *ŚiDVṛ*, xii. 4-5 ; *SiŚe*, viii. 7 ; *SiŚi*, I, xii. 10(c-d)-11(a-b).

2. Verse 28 has been taken from the *Karaṇa-prakāśa* of Brahmadeva (A. D. 1092). See *KPr*, ii. 2. Also *cf.* this verse with *SpNiT* (= *Sphhṭa-nirṇaya-tantra*), iii. 5.

CALCULATION OF DECLINATION AND LATITUDE

ततः क्रान्तिलवान् क्षेपान् आनयेत् स्वस्ववाक्यतः ॥३०॥

30. **Thereafter, one should compute the degrees of declination and celestial latitude from the tabular declinations and the tabular celestial latitudes. [See *infra*, vss. 33-37]**

NORTHERN AND SOUTHERN HEMISPHERES AND *AYANAS*

क्रियादौ सौम्यगोलं स्यात् तुलादौ दक्षिणं भवेत् ।
मृगादावयनं सौम्यं कर्क्यादौ दक्षिणं भवेत् ॥३१॥

31. **The six signs beginning with Aries constitute the northern hemisphere, and the six signs beginning with Libra constitute the southern hemisphere. The six signs beginning with Capricorn constitute the northern *ayana*, and the six signs beginning with Cancer constitute the southern *ayana*. [See *supra*, vs. 20]**

OCCURRENCE OF *VYATIPĀTA* AND *VAIDHṚTI*

ध्रुवयोगे योगनाड्यां चक्रार्धे पातसम्भवः ।
ब्रह्मयोगे योगनाड्यां चक्रे वैधृतिसम्भवः ॥३२॥

32. **The occurrence of (*Vyati*) *Pāta* is possible during the *nāḍīs* of the *yoga Dhruva*, when the sum of the longitudes of the Sun and Moon amounts to half a circle. Similarly, the occurrence of *Vaidhṛti* is possible during the *nāḍīs* of the *yoga Brahmā*, when the sum of the longitudes of the Sun and Moon amounts to a circle. [Also see *supra*, vs. 24]**

The teachings of this stanza are slightly different from those of stanza 24 above. But they are quite different from those of stanzas 13, 17 and 23.

CALCULATION OF DECLINATION

सूर्याचन्द्रमसोः गोले ज्ञात्वा लिप्तीकृतावम् ।
अनन्तेन हृतं लब्धं तयोर्वाक्यगतं भवेत् ॥३३॥[1]

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1. Verse 33 is almost the same as *KR*, i. 48.

33. **In the case of the Sun and Moon, having determined its distance from the first point of Aries or Libra, (whichever is nearer), reduce it to minutes and divide by 600 : the quotient gives the serial number of the tabular declination (crossed).**

THE DECLINATION TABLE

प्रभारत्नं[२४२] धीसवनं[४७९]
गानस्थानं[७०३] जनं धनम्[९०८] ।
देहि नित्यं[१०८८] सुगुप्रायं [१२३७]
सार्वलोक्यं[१३४७] तटिद्वपुः[१४१६] ॥३४॥

नवभार्येति[१४४०] वाक्यानि प्रोक्तानि रविचन्द्रयोः ।[1]
वाक्यान्तरहृतं शिष्टं अनन्तैर्भक्तमुत्क्षिपेत् ॥३५॥

34-35(a-b). **242′, 479′, 703′, 908′, 1088′, 1237′, 1347′, 1416′ and 1440′—these are stated to be the declinations (at the intervals of 10 degrees of the ecliptic, from the first point of Aries) for the Sun and Moon.**

35(c-d). **Then multiply the remainder (of the division) by the current declination-difference, and divide (the resulting product) by 600 : add the (resulting) quotient to the tabular declination crossed. (Thus is obtained the declination in the case of the Sun and Moon.)**

CALCULATION OF THE MOON'S LATITUDE

भूयो हीनतमश्चन्द्रो गोलवत्तमसः कलाम् ।
कृत्वा पूर्वविधानेन वाक्यान्येतानि चिन्तयेत् ॥३६॥[2]

36. **Now, subtract the longitude of the Moon's ascending node from the longitude of the Moon and reduce the resulting distance (of the Moon) from the Moon's ascending node to minutes. Then (dividing it by 600) find, as before, the serial number of Moon's tabular latitude crossed. Then make use of the following table of latitudes.**

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1. Verses 34-35(a-b) are essentially the same as *KR*, i, 49(c-d)-50.
2. Verse 36 is the same as *KR*, i. 51.

TABLE OF THE MOON'S LATITUDES

सवनानि [४७] प्रधानानि [९२]
शालायां [१३५] वासुकी [१७४]ननु ।
सेना राज्ञः [२०७] स्वगुः प्राज्ञो [२३४]
वामश्री [२५४]श्चतुरो [२६६]ऽसुरः [२७०] ॥३७॥

37. **47′, 92′, 135′, 174′, 207′, 234′, 254′, 266′ and 270′—(these are the Moon's latitudes at the successive intervals of 10° from the Moon's ascending node).**

MOON'S TRUE DECLINATION

एतास्तात्कालिके गोले समभिन्ने युतायुते ।[1]
विक्षेपाख्यफलैः ह्येषः चन्द्रक्रान्तिः स्फुटो भवेत् ॥३८॥

38. **The instantaneous declination of the Moon increased or diminished by the (instantaneous) latitude of the Moon, according as the two are of like or unlike directions, is the true declination of the Moon. [Also see *supra*, vss. 15-16]**

TIME OF *PĀTA*

रविक्रान्तेः भुजाच्चन्द्रो महांश्चेत् स गतो ध्रुवम् ।
अल्पः कोटिशशी तद्वद् विपरीते विपर्ययः ॥३९॥[2]

39. **When the *bhuja* of the Moon's longitude is greater than the *bhuja* of the longitude corresponding to the Sun's declination, (it should be understood that) the phenomenon of *Pāta* has already occurred. So is also the case when the *koṭi* of the Moon's longitude is less than (the *koṭi* of the longitude corresponding to the Sun's declination). In the contrary case, it is just the reverse (i. e., it should be understood that *Pāta* is to occur). [Also see *supra*, vs. 25]**

It is presumed that the Moon is in the odd quadrant. See *supra*, vs. 26.

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1. Verses 37-38(a-b) are the same as *KR*, i. 52-53(a-b).
2. Verse 39 is the same as *KR* i. 54.

A SPECIAL INSTRUCTION

यदा चन्द्रमसः क्रान्तिः विक्षेपाच्छोध्यते तदा ।
पदान्यत्वं विधोः कल्प्यं तदायुग्मौजभेदतः ॥४०॥

40. **When the Moon's declination (being less) is subtracted from the Moon's latitude, the designation of the Moon's quadrant, odd or even, is changed, i. e., it is taken to be even when odd, and odd when even. (Also see *supra*, vs. 16).**

CAKRĀRDHA PĀTA

यदा समानता क्रान्त्योः सूर्याचन्द्रमसोस्तदा ।
चक्रार्धं तद्विनिर्दिष्टं सर्वकर्मसु गर्हितम् ॥४१॥[1]

41. **When there is equality of the Sun's and Moon's declinations (both in magnitude and direction), then the *Pāta* is called *Cakrārdha Pāta* (or *Vyatipāta*). It is prohibited for all (auspicious) deeds. (See *supra*, vss. 2, 3 ; also see *infra*, vs. 54)**

DETAILS OF CALCULATION OF *PĀTAKĀLA*

यदा विषमता क्रान्त्योः विवरेण तयोस्तदा ।
अनन्तं [६००] गुणयेत् पूर्ववाक्यहीनापरेण तु ॥४२॥[2]

तत्काले मृगकर्क्यादिकेन्द्रे तु समभिन्नके ।
क्रान्तिवाक्यान्तरैः क्षेपवाक्यान्तरयुतायुतैः ॥४३॥

हृत्वा लब्धं कलादिश्च गतैष्ये हीनयुक् शशी ।
तत्फलं विश्व [१३] विहृतं संस्कार्यं चन्द्रवद्रवौ ॥४४॥

व्योमतर्ककरै [२६०] र्लब्धं राहोर्व्यस्तमाचरेत् ।
एवं पुनः पुनः कार्यं यावत् क्रान्ती समे तयोः ॥४५॥

1. Verse 41 is the same as *KR*, i. 55.
2. Verse 42 is the same as *KR*, i. 56.

42-45. When the declinations of the Sun and Moon are unequal, multiply 600 by their difference and divide (the product) by the sum or difference of the current tabular declination-difference and the current tabular latitude-difference, according as the Sun and Moon are in the same or different hemispheres beginning with Capricorn or Cancer: the result, obtained in minutes etc., should be subtracted from or added to the longitudes of the Moon, according to the *Pāta* has already occurred or is to occur. The same result, divided by 13, should be applied to the longitude of the Sun, as in the case of the Moon. The same result, divided by 260, should be applied contrarily to the longitude of the Moon's ascending node. This process should be iterated until the declinations of the Sun and the Moon become equal.

This rule is essentially the same as that given in the *Sūrya-siddhānta* (xi. 9-11).

The number 13 is the ratio of the Moon's daily motion (i. e., 791′) to the Sun's daily motion (i. e., 59′) ; and the number 260 is the ratio of the Moon's daily motion (i.e., 791′) to the daily motion of the Moon's ascending node (i. e., 3′)

PĀTA PAST OR TO COME

क्रान्त्योः समत्वे पातोऽथ प्रक्षिप्तांशोनिते विधौ ।
ऊने चौदयिकाद् यातो भावी तात्कालिकेऽधिके ॥४६॥[1]

46. The *Pāta* occurs when the declinations of the Sun and the Moon are equal. If, then, the Moon's longitude, as thus increased or decreased, be less than its longitude at sunrise, the *Pāta* has already occurred; if the Moon's instantaneous longitude is greater than the other, it is to occur.[1]

MOON'S MOTION IN DECLINATION

क्रान्तिवाक्यान्तरं तत्तद् ग्रहभुक्त्या विवर्धयेत् ।
अनन्तेन [६००] हृतं लब्धं तत्तत्क्रान्तिगतिर्भवेत् ॥४७॥

1. Verse 46 has been taken from the *Sūrya-siddhānta*, with हीनेऽर्धरात्रिकात् replaced by ऊने चौदयिकात् . See *SūSi*, xi. 12.

क्षेपवाक्यान्तरं तत्तत् चन्द्रगत्या च तद्गतिः ।
मृगकर्क्यादिकेन्द्रे तु क्रान्तिगत्या युतायुता ॥४८॥

47. **Multiply the various differences of the tabulated declinations by the daily motion of the planet and divide by 600. Thus are obtained the daily changes in declination (for the various elemental arcs).**

48. **Similarly, the various differences of the tabulated latitudes (of the Moon) multiplied by the Moon's daily motion (and divided by 600) yield the daily changes in (the Moon's) latitude (for the various elemental arcs). These added to or subtracted from the corresponding daily changes in declination, according as the Moon is in the six signs beginning with Capricorn or in those beginning with Cancer (give the daily changes in the Moon's true declination).**

DIAMETERS OF THE SUN AND MOON

षड्[६]युता दस्र[२]भक्ता च
दश[१०]युक् तत्व[२५]भाजिता ।
गतिः चन्द्रार्कयोः, विम्बौ तत्तत्काले विदुर्बुधाः ॥४९॥

49. **In one place, add 6 to the Sun's daily motion (in terms of minutes) and divide the sum by 2; in another place, add 10 to the Moon's daily motion (in terms of minutes) and divide the sum by 25 : the results, say the learned, are the diameters (in terms of minutes) of the Sun and Moon (respectively) for the time of calculation.**[1]

That is :

$$\text{Sun's diameter} = \frac{\text{Sun's daily motion} + 6'}{2}$$

$$\text{Moon's diameter} = \frac{\text{Moon's daily motion} + 10'}{25}$$

In particular :

$$\text{Sun's mean diameter} = \frac{59' + 6'}{2} = 32'\cdot 50$$

$$\text{Moon's mean diameter} = \frac{791' + 10'}{25} = 32'.$$

1. Also see *supra*, ii. 2, p. 42.

TIME OF OCCURRENCE OF THE *PĀTA*

रवीन्दुमानयोगार्धं षष्ट्या सङ्गुण्य भाजयेत् ।
क्रान्तिगत्यन्तरेणाप्तं स्थित्यर्धं नाडिकादि तत् ॥५०॥[1]

स्थिरीकृतौदयिकयोः इन्द्वोः विवरलिप्तिकाः ।
षष्टिघ्नाश्चन्द्रगत्याप्ताः पातकालस्य नाडिकाः ॥५१॥[2]

50. **Multiply half the sum of the diameters of the Sun and Moon by 60 and divide (the product) by the change in declination-difference, per day, of the Sun aud Moon : the result is the semi-duration of *Pāta* in terms of *nāḍīs* etc.**

51. **The minutes of difference between the Moon's longitude obtained by iteration and the Moon's longitude calculated for sunrise, when multiplied by 60 and divided by the Moon's daily motion (in terms of minutes), gives the time of occurrence of the *Pāta* (reckoned from sunrise).**

THE MIDDLE OF *PĀTA*

पातकालः स्फुटो मध्यः सोऽपि स्थित्यर्धवर्जितः ।
तस्य सम्भवकालः स्यात् तत्संयुक्तोऽन्त्यसंज्ञकः ॥५२॥[3]

52. **The true time of occurrence of the *Pāta* is the middle of the *Pāta* ; that diminished by the semi-duration of the *Pāta* is the time of its commencement ; and that increased by the semi-duration of the *Pāta* is the time of its end.**

RECURRENCE OF *PĀTA*

यस्मिन् दिने समुद्भूतः पातस्तस्मात् त्रयोदशे ।
पुनश्चन्द्रार्कयोः क्रान्त्योः साम्ये पातस्य सम्भवः ॥५३॥

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1. Verse 50 has been taken from the *Sūrya-siddhānta*, with the word तयोर्भुक्त्यन्तरेण replaced by क्रान्तिगत्यन्तरेण . See *SūSi*, xi. 14.
2. Verse 51 has been taken from the *Sūrya-siddhānta*. See *SūSi*, xi. 13.
3. Verse 52 has been taken from the *Sūrya-siddhānta*. See *SūSi*, xi. 15.

53. **On the thirteenth day from the day of occurrence of a *Pāta*, the declinations of the Sun and Moon being equal, there is possibility of occurrence of a *Pāta* (again). [Also see *supra*, vss. 8, 18, 24]**

POSSIBILITY OF *PĀTA*

अयनांशयुतार्केन्द्वोः योगे व्यप्रख्यसम्भवः ।
षड्भे द्वादशराशौ तु वैप्रपातस्य सम्भवः ॥५४॥

54. **When the sum of the longitudes of the Sun and the Moon, corrected for the precession of the equinoxes, amounts to six signs, there is possibility of the occurrence of the phenomenon called *Vyatipāta* (*vya+pra*=the *Pāta* with *vya* as the first letter) ; when that sum amounts to twelve signs, there is possibility of the *Pāta* called *Vaidhṛti* (*vai+pra+pāta*=the *Pāta* with *vai* as the first letter).**

IMPOSSIBILITY OF *PĀTA*

चापान्नृयुग्मान्तगते च सूर्यक्रान्तेर्मृगात्कर्कटकादिकेन्दोः ।
क्रान्तिः स्फुटाऽल्पा च यदा तदानी-
मसम्भवत्येव हि पातयोगः ॥५५॥

55. **When the true declination of the Moon, lying in the beginning of Capricorn or Cancer, falls short of the declination of the Sun lying at the end of Sagittarius or Gemini, there is no possibility of the occurrence of a *Pāta*. [Also see *supra*, vss. 6, 27]**

Mādhava, in his *Siddhānta-cūdāmani*, writes :

"When the declination of the Moon, lying in an even quadrant, falls short of the declination of the Sun, lying in an odd quadrant, equality of their declinations is not possible ; in the contrary case, it is possible."[1]

इति करणरत्ने महापाताध्यायः[2]

Thus ends the Chapter dealing with *Mahāpāta* in the *Karaṇa-ratna*.

---

1. रवेरोजपदक्रान्तेश्चन्द्रयुग्मपदोद्भवा ।
स्वल्पा चेन्न तयोः क्रान्त्योः साम्यं स्यादन्यथा भवेत् ॥
Also see *ŚiDVṛ*, I, xii 4 ; *SiŚe*, viii. 3; and *SiŚi*, I, xii. 7.

2. After this colophon the mss. have the following verse which is evidently due to the scribe :
यादृशं पुस्तकं दृष्टं तादृशं लिखितं मया ।
अबद्धं वा सुबद्धं वा मम दोषो न विद्यते ॥

APPENDIX 2

SPECIAL TERMS AND PROPER NAMES

[The numbers refer to the relevant pages]

अयन (उत्तरायण or दक्षिणायन), 73, 101; (=अयनग्रह), 25; (=अयन-चलन), 25; सौम्य or उत्तर —, 109, 112; याम्य or दक्षिण—, 109, 112; (=sign or house), 104, 109; —वलन, 25

अयनांश (precession of the equinoxes), 105, 106, 107

अवन्ती (Ujjain), 23

आर्यभट (Āryabhaṭa I), 81; —शास्त्र, 1

उज्जयिनी (Ujjain), 21

करण (astronomical *karaṇa* text) 1, 2; (=13), 12, 88; —अब्द (year of the *karaṇa* text), 12; —रत्न, 1.

कल्प (a period of 1008 *yugas*), 14

काष्ठा (arc), 70

गुण (Rsine), 77

गोजन्म (name of author's father), 1; —सुनु, 71

गोल (northern or southern hemisphere), 25, 28, 29, 89, 107; सौम्य —, 112; दक्षिण—, 112

ग्रह (=ग्रहण, eclipse), 57, 106

ग्राह्यग्राहकसमेतबिम्ब (=सम्पर्क, sum of the diameters of the eclipsed and eclipsing bodies), 58

घोर (पात), 104, 105

चतुर्युग (*yuga* of 43,20,000 years), 14

चलांश (=अयनांश), 103

छन्न (eclipsed part), 48

जीव (=जीवा, Rsine), 104

तन्त्र (astronomical *tantra* text), 2

तम (Shadow), 49, 50

देव (name of our author), 1, 41, 62, 71, 80, 101; —आचार्य, 101

द्विभव (पात), 104

नष्ट (=अवम or अवमदिन, omitted lunar day), 6; —दिन (=अवमदिन), 2, 9; —शेष (=अवमशेष), 6

पञ्चसिद्धान्तिनाम्, 14

पद (=step), 52; (=word-chronogram), 63, 64, 65.

पर्व (end of पूर्णिमा or अमावास्या), 43, 52-54

पात (Moon's ascending node), 86; (=महापात or व्यतिपात), 100, 103, 104, 108

पुराण (=18), 87, 93

प्रग्रह (first contact in an eclipse), 58

प्रग्रहण (=प्रग्रह), 43, 48, 49, 57

फणि (=राहु), 43, 51, 104; (=Shadow), 43, 45, 46

भट (=आर्यभट), 14

भवन (=राशि, sign), 58, 68

भुजङ्गराज (=राहु), 12

मण्डल (circle, 360°), 101

मनु (a period of 72 *yugas*), 15

मालवनगर (Nagara or Karkoṭanagar in Rajasthan), 21

मेरु (north Pole), 21

युतबिम्बार्ध (=सम्पर्कार्ध), 58, 61

योगभानि (=योगाः), 31
राहु (=Moon's ascending node), 9, 41, 43, 45, 97, 107; (=Shadow), 42, 57;—भ्रम (path of Shadow), 51; —मुख (Moon's ascending node), 9.
लङ्का, (a hypothetical place in 0 long. and 0 lat.), 21, 23
वत्साख्यभद्रपुरी (=वात्स्यपुर, Basim in Mahārāṣṭra), 21
विद्या (=18), 88
वाक्य (letter-chronogram), 34, 35; —प्रमा (chronogram-number), 34
विक्षेप (=क्षेप, Addition), 73
विषुवत् (equator), 103, 104; —छाया (equinoctial midday shadow), 23, 24, 54, 58, 72;—नाड्यः (latitude in *nāḍīs*), 54;— भवगुण (Rsine of latitude), 77
वैधृत or वैधृति, 32, 101, 107
वैप्रपात (=वैधृतपात), 119
व्यतिपात or व्यतीपात, 32, 33, 101,
व्यप्रख्य (=व्यतीपात), 119
व्यङ्गुल (one sixtieth of an *aṅgula*), 24, 54
शकवर्ष (year of *Śaka* era), 1, 25
शङ्कु (=gnomon), 68; (=*iṣṭahṛti*), 77
संक्रान्ति (=क्रान्ति, declination), 110
सम्पर्कार्ध (half the sum of the diameters of the two bodies in contact), 45, 46
सहितबिम्बार्ध (=सम्पर्कार्ध), 49
सार्पमस्तक(पात), 32
स्थानेश्वर (a sacred place near Thanesar in Haryana), 21
स्फुटत्रय (=दर्शनसंस्कारत्रय, the three visibility corrections), 76
स्वामीनगर (Samehalli in Mysore), 21

WORD-NUMERALS

0 अम्बर, आकाश, ख, गगन, नभ, वियत्, शून्य
1 इन्दु, रूप, शशि
2 अक्षि, अश्वि, कर, नेत्र, पक्ष, बाहु, भुज, यम, यमल, युगल, युग्म
3 अग्नि, गुण, दहन, पावक, लोक, वह्नि, शिखि, हुतभुक्
4 अब्धि, अम्भोनिधि, कृत, जलधि, वारिधि, वेद, श्रुति
5 इषु, बाण, भूत, विषय, शर
6 अङ्ग, ऋतु, तर्क, रस
7 अग, अद्रि, गिरि, नग, मुनि, शैल, स्वर
8 मङ्गल, वसु
9 छिद्र, नन्द, निधि, रन्ध्र
10 दिक्
11 रुद्र, शङ्कर
12 अर्क, रवि
13 करण
14 मनु
15 तिथि
16 अष्टि
18 पुराण, विद्या
20 नख
24 जिन
25 तत्त्व
27 भं
32 दन्त

APPENDIX 3

INDEX OF VERSES AND KEY PASSAGES

[The numbers refer to the relevant pages]

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